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INDIAN FOREST RECORDS.

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Note on the Distillation and Composition of Turpentine Oil from the Chir Resin and the Clarification of Indian Rosin.

BY

PURAN SINGH, F.C.S.,

Chemist at the Forest Research Institute, Dehra Dun, India.

PART I.

INTRODUCTION.

UP to the present, the distillation of turpentine oil in India has not been carried out to any great extent, though the industry is of considerable promise. Attempts are being made by the Forest Department of the Punjab and the United Provinces to bring larger areas of Pine forests under tapping, and it may be hoped that this industry will be greatly extended in near future. Out of the different species of Indian Pines, the Indian turpentine oil is being, at present, distilled mostly out of Chir (*Pinus longifolia*) resin, which though most abundant does not seem to be capable of yielding oil of the same quality as the resins of *Pinus Khasya*, *P. Merkusii* and *P. excelsa*. The latter resins are still under examination, and they will form the subject of a separate report as soon as the required data are obtained.

The Forest Department has two distilleries in the United Provinces: one, a small one, at Kalsi (Chakrata Division), and the

other at Bhowali (Naini Tal Division), the latter being worked on a comparatively large scale. One has recently been started at Shahdara in the Punjab where steam is used in place of water for distillation. Though the quantity of turpentine and colophony turned out by the two departmental factories finds a ready sale, yet there is room for improvement. Complaints have been received from time to time that the Indian oil dried more slowly than the imported American turpentine. In a criticism received from a reliable source of Indian turpentine oil by the Reporter on Economic Products to the Government of India, and forwarded to the Forest Economist in 1907, for information, it was stated that its smell, its inferior drying power, and its less volatile constituents place it far below the American and the French turpentines, and that it would never be able to compete in the European market with American, French or Russian turpentines, unless greatly improved. There is a good deal of truth in this criticism as regards the oil derived from this particular species, which owing to its different chemical composition cannot come up to the American and French oils consisting mostly of pinene, but if prepared by adopting better methods of distillation, it is better than the Russian turpentine oil and is not much inferior to the American oil when used for paints, varnishes, etc.

In 1908, some difficulty arose about the sale of turpentine oil produced at Bhowali, which was said to leave a greasy residue on evaporation and was, therefore, unsuitable for varnish. Accordingly, Mr. P. H. Clutterbuck, the then Deputy Conservator of Forests, Naini Tal, instituted an enquiry into the matter with the object of determining the causes of the low drying power of the Indian oil and ascertaining whether those causes proceeded from the method of distillation employed, and to decide whether it should be given up in favour of steam distillation.

After having thoroughly gone into this question by examining the different fractions of the crude turpentine oil, it was found that the crude oil as then distilled contained about 35 per cent. of heavy turps, the whole or the portion of which must be eliminated to free the oil of the defect complained of. The greasy residue was traced to the presence of these heavy turps in the oil. The most natural method of refining the oil, therefore, appeared to be the elimination of the total 35 per cent. of heavy turps from the crude oil and its

rectification by redistillation until on fractional distillation it would nearly all pass over below 167°—170° C. Some trouble was taken to find out if any portion of the 35 per cent. could be utilized.

An oil of fairly good quality was produced by redistilling the last portion of the crude oil to the extent of 75 per cent. and mixing it with the first three parts of the crude distillate. An oil was thus obtained which had only 9 per cent. of that heavy residue distilling above 172° C. This oil sold at a fairly good rate, but certain purchasers still rejected it as unsuitable. A market was also found for the heavy turps contained in the crude oil, as it could be used for the manufacture of printing inks.

After preliminary work on redistillation, most of which was done in conjunction with Mr. P. H. Clutterbuck at Bhowali, the enquiry was pushed further with a view to finding out some better method for distilling *Pinus longifolia* resin at low temperatures. It was observed that it is in the process of distillation whether by water or by steam, both of which have to be necessarily carried out at high temperatures to secure the total yield of oil, that the more labile constituents of Chir oil change into higher terpenes under the influence of excessive heat, resulting in the deterioration of the oil. No attempt seems ever to have been made on a commercial scale in India to produce this oil in its purest form. A suitable method was devised for distilling the oil in its original purity in the Laboratory of the Forest Research Institute. The fractional distillation of the oil, which was obtained by distilling a mixture of crude resin with a small quantity of acetic acid or methylated spirit by steam at a temperature of about 100° C., confirmed the fact that it was the high temperature at which distillation is carried out that spoils the oil. The oil thus distilled had only about 4—6 per cent. of turps which distilled above 167° C., which, as said above, in the case of water-distilled crude oil amounted to 35 per cent., boiling above 172° C. It was thus proved that the quality of the oil mainly depends on the temperature of the still; the lower this is kept the better the quality of the oil. This laboratory method was tried on a fairly large scale at Bhowali and a fairly large quantity of the oil was distilled at 100° C. by using an ordinary and somewhat crude form of still. The commercial opinions received were fairly encouraging.

Besides the oil which was distilled very slowly with 70 per cent. spirit and which was found upon examination to be of a uniform and good quality, a few lots were also produced under varying conditions of distillation for experimental purposes. Some samples of these experimental distillations at Bhowali, which were made by rapid distillation at comparatively high temperature with dilute spirit, gave no better results than those obtained by water distillation. Though it is not possible to produce turpentine oil of the same composition as French and American oils, yet if the method described and advocated in Chapter V of this Note were to be adopted, a great improvement in quality could be effected.

The steam distillation was tried in the Laboratory by passing steam into the resin from a small laboratory boiler, but it was noticed that in this way only a small fraction of the oil could be distilled. The temperature had, therefore, to be raised to obtain the full yield of the oil, and it rose to 140° C. The quality of the crude oil thus obtained was not different from that obtained by water distillation, and in this respect, it was concluded, the steam had no advantage over water in the distillation of the Chir resin.

This investigation has continued, off and on, for the last five years and has been of a technical nature. The fractional distillation tests throughout this investigation were carried out in an ordinary fractional distillation flask at the usual barometric pressure of Dehra Dun, say about $27\frac{1}{2}''$, and the fractions have always been calculated by volume. The results with a Young's 12-bulb dephlegmator undoubtedly would have been different, but the absolute accuracy of the fractional distillation of various samples examined was neither aimed at, nor necessary; they have only a comparative significance and care has been taken to always distil fractionally a sample of American oil side by side with samples under examination, under the same conditions for purposes of comparison. To check the figures obtained, three samples were also sent to Dr. J. W. Leather at Pusa, who was kind enough to examine them; the results thus obtained agreed with slight variations with those obtained at Dehra Dun. The figures given, therefore, may be taken as correct for comparative purposes.

On the whole, the results of the enquiry into the distillation of Chir oil are considered worth recording, and, therefore, the details

of the work done during the last five years are published for information.

The writer takes this opportunity of offering his thanks to Messrs. H. P. Clutterbuck, B. B. Osmaston, and E. A. Smythies for their generous help given from time to time and for allowing him to use their stills for his large-scale experiments. He is also indebted to Dr. J. W. Leather for the assistance given him. He is obliged to Rai Sahib Bishen Dass, Personal Assistant to the Manager, and Mr. Keatinge, the Chief Store-keeper, North-Western Railway, for the help given in determining the nature of the turpentine requirements of Railway Workshops.

CHAPTER I.

(i) General Properties of Turpentine Oil.*

Turpentine oil is the name applied to the product obtained by distillation with water vapour of an oleo-resin derived from the species of *Pinus*, *Picea* and *Abies* of the family *Pinaceæ*. This oleo-resin, (also called crude turpentine), is a solution of resin in volatile oil, and when the latter is removed by distillation, the former, namely, the resin, is left as a residue which purified and strained is known as rosin or colophony.

The principal turpentine oils used in Europe are the following:—

1. American oil of turpentine, from *Pinus australis. P. Tæda* and others growing in the United States of America.
2. French turpentine oil, obtained from *Pinus maritima* and *Pinus Pinaster*.
3. Austrian turpentine oil from *Pinus Laricio*.
4. Venetian turpentine oil from the Venice turpentine, the produce of *Larix europea*.
5. Russian turpentine oil from *Pinus sylvestris*.

Of all these the most widely employed oils throughout the world are the first two, namely, the American and the French.

* Taken mostly from Gildmeister and Hoffman's "Volatile Oils."

Pure freshly distilled turpentine oil is a colourless, limpid, mobile liquid, which is neutral to the test paper. It has a peculiar odour, which varies according to the age. The sharp odour observed in old oils is believed to be due to the presence of an aldehyde, which is formed by the action of the atmospheric oxygen on the oil.

Turpentine oil is volatile at ordinary temperatures and becomes slightly resinified by long contact with air.

Crude turpentine oil gives a faintly acid reaction due to small quantities of free formic and acetic acids present. It has, therefore, to be rectified with lime for certain purposes. Even pure oil, which has not been kept in well-closed vessels, shows an acid reaction due to the oxidation products formed.

Solubility.—Turpentine oil dissolves with difficulty in alcohol, especially in dilute alcohol. The solubility, however, in this reagent increases with age, owing to the formation of readily soluble oxidation products. A good turpentine oil in general requires 5—9 parts of 90 per cent. alcohol to effect a clear solution. Ether, chloroform, carbon bisulphide, benzene, petroleum ether, glacial acetic acid and the fatty oils dissolve turpentine oil in almost all proportions.

Turpentine oil is extensively employed for dissolving fats, resins, caoutchouc and is used in the arts for the preparation of varnishes and paints.

Boiling point.—The greater portion of good turpentine oil (75—80 per cent.) boils between 155°—163° C.

Rotatory power.—The several varieties of turpentine oil have different rotatory powers, some being dextro-rotatory or dextrogyrate, others lævogyrate. The French turpentine oil is invariably strongly lævogyrate while the American is generally dextrogyrate and seldom lævogyrate. The optical activity of the American oil as determined by Dr. Armstrong is αD* $= +9° 30'$ to $+14° 17'$ and that of French turpentine $\alpha D = -30°$ to $-30° 30'$.

Specific gravity.—The specific gravity of a good turpentine oil is always between 0·862 and 0·872 at 15·55° C. The oil of commerce, however, is sometimes found to have a greater specific gravity than the latter limit.

* α D is the observed angle of rotation with sodium light in a 100 mm. tube.

Influence of air on turpentine oil.—Turpentine oil when allowed to stand in open vessels suffers a rapid change, especially if it contains water. The oil gradually becomes rancid and the specific gravity, boiling point, and solubility in 90 per cent. alcohol increase; the originally neutral oil becomes acid and resinifies. All these changes are due to a slow oxidation caused by the atmospheric oxygen. Turpentine oil when oxidized in the presence of moisture has been shown to contain hydrogen peroxide, which makes it an active oxygen carrier, that is, turpentine, whether dry or moist, when charged with oxygen, has the capacity to convey oxygen to such substances that are not directly oxidizable with the atmospheric oxygen.

Composition.—Turpentine oil is a mixture of hydrocarbons called terpenes of the general fomula $C_{10}H_{16}$. Though these hydrocarbons are identical in their chemical composition, they have yet distinctive physical properties. The chief constituent of the turpentine oil is pinene (b. p. 155°—156° C.), which is a very labile terpene. In production of turpentine oil, part of the pinene undergoes decomposition, and the decomposition products become mixed up with the oil. As already stated, the oil contains traces of formic, acetic and other resin acids which at higher temperatures react on pinene producing dipentene and other polymeric terpenes.

When turpentine oil is subjected to fractional distillation, those of the constituent terpenes that have a lower boiling point than the others pass over first, while those having a high boiling point come over next. Thus the oil can be separated into various fractions, which are mixtures in varying proportions of two or more different constituent terpenes. It may be remarked here that though the observation of the amounts of the different fractions of the same oil by different observers seldom agree, as they all depend on the form of the distilling flask, the rapidity of distillation and the barometric pressure, yet, for all practical purposes, the fractional distillation of different samples gives a very good idea of the quality of the oil. The greater the amount of the fraction (passing over below 165° C.), the better is the quality of the oil. A good oil in general passes over almost entirely below 180° C., and the greater the amount of the fractions passing over above 180° C. inferior will be the quality of the oil.

As regards the fractions of the American oil, the opinion of Dr. R. S. Morrell, M.A., Ph.D., who regards fractional distillation of the turpentine oil as its chief test, may be quoted here:—"From several years' experience in the examination of American turpentine oil, I rely chiefly on the behaviour of the oil on fractional distillation. Using a Young's 12-bulb dephlegmator, a good American turpentine gives about 90 per cent. distilling over between 155° and 165° C. The variation in the behaviour of high class American turpentine on fractional distillation is very small from year to year. Any alteration in the colour and smell of the turpentine is accompanied by a change in the quantity and quality of the fractions."—(*Journ. Soc. Chem. Ind.*, No. 5, Vol. XXIX, page 241.)

Some of the more important properties of the principal turpentine oils are given below:—

American oil of turpentine.—The specific gravity of the crude oil lies between 0·865 and 0·870. Freshly distilled oil is mostly lighter than the crude or the old oil. On fractional distillation 85 per cent. passes over between 155°—163° C. For solution crude American oil requires 5 parts and the rectified American oil 5—6 parts of 90 per cent. alcohol.

French oil of turpentine.—Specific gravity varies from 0·859 to 0·876, but generally the limit is 0·865—0·876. In all other properties it agrees with the American oil. Crude French oil requires 7 and rectified oil 6.5—7 parts of 90 per cent. alcohol to give a clear solution.

Austrian turpentine oil.—Specific gravity = 0·866; it is soluble in 8—6 parts of 90 per cent. alcohol. On fractional distillation, it gives the following fractions:—

159° C.	21 per cent.
159°—160° C.	56 „
160°—167° C.	18 „
Residue	5 „

Venetian turpentine oil.—Specific gravity = 0·878. Upon fractional distillation, the oil distils over between 155° and 190° C., the larger portion going at 157° C.

*Russian turpentine oil.**—This oil is derived from *Pinus sylvestris, L.* Its specific gravity varies between 0·862 and 0·872, the angle of rotation from $D = +15° \, 25'$ to $+24°$ (Armstrong). It boils between 155°—180° C. Upon distillation, Tilden obtained the following fractions:—

160°—171° C.	10 per cent.
171°—172° C.	63 „
172°—185° C.	24 „

The following figures for two samples of Russian turpentine oil have been recorded in the Bulletin of the Imperial Institute, London:—

	I.	II.
Specific gravity at 15·5° C.	0·866	0·884
Optical rotation in 100 mm. tube.	+14° 29′	+16° 20′
Fractions boiling below 165° C.	16 per cent.	18 per cent.
165°—170° C. . . .	43 „	36 „
170°—175° C. . . .	20 „	18 „
Residue above 175° C. .	21 „	23 „

Philippine turpentine oil.—This is derived from the oleo-resin of *Pinus insularis*, Endl. The oil has been examined by B. T. Brooks, (see Philippine *J. Sci.*, 1910, 5, 229—231). The oil was found to consist for the greater part of the ordinary pinene, 96 per cent. distilling between 154° and 165·5° C.

Burma turpentine oils.—They are obtained from *Pinus Khasya* and *Pinus Merkusii.* Both these oils are similar in their properties. Specific gravity of the oil from *Pinus Khasya* at 20° C. is 0·8627 and that of *Pinus Merkusii* is 0·861. On fractional distillation, both these oils distil within a very narrow range of temperature near 155° C., though the oil from *Pinus Khasya* has a larger amount of some high boiling constituent. Dr. Armstrong is of opinion that both these oils are of the highest quality and good for every purpose for which French or American turpentine is used. They are like French and American pinene oils.

* See "Volatile Oils" by Gildmeister and Hoffman, page 256, and also *Indian Forester*, September 1911, page 519.

Indian turpentine oil from Pinus longifolia.—Most of the Indian oil has up to date been obtained from *Pinus longifolia.* The chemical composition of this oil has been the subject of investigation at the Imperial Institute, London, (*vide* Chapter II and Appendix D). Like Russian turpentine oil, it consists of pinene and sylvestrene. According to the experiments conducted at the Forest Research Institute, Dehra Dun, the proportion of high-boiling terpenes increases or decreases as the oil is distilled at a high or low temperature. The oil distilled at a low temperature contains a greater amount of low boiling terpenes and consequently is of better quality than that in which the low boiling terpenes are polymerised into higher terpenes by excessive heat.

The specific gravity of the redistilled oil obtained by distilling at high temperature is between 0·963 and 0·864 at 22° C. On fractional distillation in an ordinary fractional distillation flask, 80 per cent. of this oil passes below 165° C. The sample of oil redistilled twice gave the following fractions:—

155°—163° C.	55	per cent.
163°—165° C.	37·5	,,
165°—172° C.	12·5	,,

(ii) Methods of Turpentine Distillation.

There are various methods of distilling turpentine oil both from the resinous wood and from the oleo-resins. A brief description of some of the processes for distilling the oleo-resins is given below.

Furnace heat process.—This consists in gradually raising the temperature of crude resin to 150° C. and even higher by the direct heat from the furnace. It is more like a dry distillation process. Towards the close of the operation water is poured into the still when brisk effervescence takes place and the remaining oil is somewhat rapidly distilled. This is a very primitive method. It has been mostly given up in favour of mixed distillation and steam distillation processes.

Mixed method of distillation.—In this process the crude resin placed in a sort of steam still set up on a furnace is heated to about 120° C. when steam is admitted. In this process, steam serves

a three-fold purpose, as an agitator, as a disintegrating agent and as a means of conveying the vapours of the spirits of turpentine to the condenser.

The temperature of 120° C. is too low and the distillation proceeds too slowly. While carrying out this process in the Laboratory, the temperature had to be raised up to about 140° C. It may be noted here that if steam is passed without initially heating the crude resin, too much water comes over and very little oil of turpentine, so much so that commercially speaking this method of distillation is inadmissible. Besides, the yield of oil is extremely poor.

Superheated steam distillation.—This is the most recent method that is in general use. The crude resin is kept in a steam jacket, fitted inside with a steam coil. The temperature of the chamber is made to rise to 150° C. by letting steam into the coil and the jacket at a pressure of 4 to 7 kilograms per sq. cm. At this temperature the volatile constituents of the resin come over. The vapours are led into a closed hollow cylinder, a sort of tubular condenser where mechanical arrangements are perfected so as to cause a partial vacuum during the process of distillation. This process, therefore, is a combination of vacuum distillation and steam distillation. It is said that oil of turpentine of a very good quality is obtained by this process.

Another description of the superheated steam method is that the crude resin placed in a steam still is kept hot by means of a closed steam coil at 100° C., and when it reaches that temperature, superheated steam is let in. This process is said to be a very rapid one.

Vacuum distillation.—While, in connection with the distillation of *Pinus longifolia* resin, the writer of this Note was considering the adoption of the principle of vacuum distillation on a commercial scale in India, he was pleased to read the account of a patent, taken out in France, for distilling turpentine *in vacuo*. In this apparatus the crude turpentine is heated *in vacuo* and mechanically agitated at the same time. The apparatus used for the purpose has mechanical stirring arms and has its outlet connected with a reflux condenser, so that the heavier volatile substances fall back into the heating chamber, whilst the most volatile constituents

pass on to a second condenser. After the material has been sufficiently heated, air is admitted into the apparatus and the mass is allowed to stand in order to allow the solid impurities to sink. On this occurring they and the water are separately drawn off. (For further details see French patent 409,026, November 13th, 1909, and also see a reference to it in *Journal Soc. Chem. Indus.*, June 13th, 1910, page 769.)

CHAPTER II.

The Chemical Composition of Turpentine Oil from *Pinus longifolia.*

The turpentine oil from *Pinus longifolia* has been examined at the Imperial Institute, London, and according to the investigation results as printed in the interim and subsequent reports (*vide* Appendix D), the oil consists of lævo-pinene, sylvestrene and a small quantity of a still higher terpene, which has not yet been isolated. It, therefore, materially differs in its composition from the French and American oils which almost wholly consist of pinene, and substantially resembles the Russian turpentine oil in this respect. Its peculiar odour is also due to the presence of sylvestrene.

The crude resin of *Pinus longifolia,* examined at the Forest Research Institute, gave the following constants:— .

Oil	22 per cent.
Rosin	60 ,,
Acid number	129·13
Saponification number (determined hot after one hour).	139·00
Ester number	9·87
Iodine number (Hubel, 18 hours) . . .	228·07

The crude oil distilled at low temperature through acetic acid gave an iodine number of 361·36 and the same when rectified gave 326·00.

The crude water distilled oil gave 35 per cent. of heavy turps boiling above 170° C. The same partially rectified gave 9 per cent.

of the fraction above 172° C. The same thoroughly rectified by redistillation had only 5 per cent. of this fraction. The oil made "extra fine" by redistilling it three times distilled completely below 172° C.

The defect of the oil leaving a greasy residue on evaporation is partially due to the presence of sylvestrene and mainly to that of the heavy turps boiling above 170° C. It will be seen that this defect is capable of being remedied by subjecting the oil to the usual process of rectification, which has not generally been resorted to in the forest distilleries.

It has also been noticed that the excess of the high boiling terpene is due to the high temperature obtained in water distillation. The crude oil, distilled at about 100° C. as detailed in Chapter V, gave an oil 90—96 per cent. of which passed below 167° C. A very pure oil was obtained by one rectification of this oil. If the redistillation were to be pushed further an oil extremely rich in light terpenes could be obtained, but the cost of refining it to that extent would be prohibitive on a commercial scale.

The water distilled oil rectified by redistilling it twice, the crude oil distilled through methylated spirits and the latter redistilled once were kept in stoppered bottles in the laboratory for a year and a half. The first became very yellow depositing a thick yellow resinous matter at the bottom, the second became slightly pale depositing a trace of slightly yellow resin, and the third showed no change in colour and deposited no sediment. The behaviour of these three oils evidently shows the superiority of the oil distilled at a low temperature to that distilled with water at a high temperature, though both were inferior to the redistilled spirit-distilled oil in that they deposited a resinous sediment.

In conclusion, according to the various results of fractional distillations recorded in this Note, it may be stated that an oil containing a high percentage of low boiling terpenes can be distilled from the resin of *Pinus longifolia* if distillation is carried on slowly and at a low temperature, say, the contents of the still to be at 100° C. This oil, as it will be evident from commercial opinions cited in Chapter V, judged as a material for varnish-making and for use in paints, etc., is nearly equal to the imported oils in the Indian market.

CHAPTER III.

Steam Distillation* *versus* Water Distillation.

It was first proposed to determine to what extent the quality of turpentine oil was improved by replacing the present method of distillation by the steam distillation process. Accordingly two samples of crude oleo-resin, one from the Jaunsar Division and the other from Naini Tal, were subjected to steam distillation in a small steam still in the laboratory with results detailed below:—

Jaunsar sample.—This oleo-resin gave 20 per cent. by weight of turpentine oil. On fractional distillation, the latter gave the following fractions:—

Steam distilled turpentine oil.

(Kalsi.)

160°—165° C.	25·5 per cent.
165°—172° C.	39·0 ,,
172°—180° C.	13·0 ,,
180°—200° C.	12·5 ,,
Residue above 200° C.	10·0 ,,

The steam distilled oil rectified by redistillation gave the following fractions:—

Up to 165° C.	80 per cent.
165°—172° C.	15 ,,
Residue above 172° C.	5 ,,

The specific gravity of the redistilled oil was found to be 0·8635 at 22° C.

* Steam distillation mentioned here consisted in passing steam into the resin placed in a steam still gradually heated to about 140° C. and distilling off the whole of the turpentine oil at that temperature. It was found that the total yield of the oil could not be obtained in the Laboratory below that temperature. According to various authorities, the temperature of the resin even in superheated steam distillation process has to be raised to 150° C. when distillation is done on a large scale.

The sample of turpentine oil (specific gravity at 30° C. = 0·867) as at present distilled at Kalsi was washed with water and fractionated with the following results:—

The crude oil as distilled at present.
(At Kalsi.)

160°—165° C.	40* per cent.
165°—172° C.	31 ,,
172°—180° C.	14 ,,
180°—200° C.	4 ,,
Residue above 200° C.	11 ,,

The yield of turpentine oil by the present method at the Kalsi Factory is 18—19 per cent. by weight.

Naini Tal sample.—As it will be clear from the results given below, the sample of the oleo-resin from the Naini Tal Division seems to be richer† than that from Jaunsar. The Naini Tal sample yielded on steam distillation 22 per cent. by weight of the turpentine oil, which gave the following fractions:—

Steam distilled turpentine oil.

(Naini Tal.)

Up to 170° C.	62·5 per cent.
170°—180° C.	13·0 ,,
180°—200° C.	12·5 ,,
Residue above 200°C.	12·0 ,,

The same rectified gave the following fractions:—

Up to 165° C.	80 per cent.
165°—172° C.	15 ,,
Residue above 172° C	5 ,,

* This oil has 71 per cent. passing below 172° C., while the crude oil of Bhowali has only 64·5 per cent. passing below that temperature. This difference is due to the rate of distillation. At Kalsi they distil much more slowly than at Bhowali.

† But this may be due to various causes, such as incidental evaporation, atmospheric oxidation, etc.

The turpentine oil as turned out at Bhowali (Naini Tal) (specific gravity at 30° C. = 0·869) gave the following fractions:—

Crude turpentine oil distilled at Bhowali.
(Naini Tal.)

160°—165° C.	27·5 per cent.
165°—172° C.	32·5 ,,
172°—180° C.	17·5 ,,
180°—200° C.	9·0 ,,
Residue above 200° C.	13·5 ,,

The yield of turpentine oil at Bhowali is between 19—20 per cent. by weight.

It will be evident from the above figures that the quality of the crude oil from both processes is nearly the same, but the oil rectified by redistillation is really much lighter than the crude oil and is of a uniform quality. About 80 per cent. of this rectified passes below 165° C.* But it will be shown later on that the crude oil obtained by water distillation can also be improved to the same standard, by means of redistillation.

Colophony, as obtained from steam distillation, appears to contain a greater amount of moisture and less of other volatile matter than the colophony obtained by the water distillation process, and, therefore, if the former were gently heated on an open fire for some time, it would be quite as good as the imported stuff. There is very little difference in the two samples in their acid and saponification numbers. (See Part II of this Note.)

Water distillation.—In this process, the temperature of the still charged with crude oleo-resin is raised to 165°—175° C. before the distillation actually begins. As soon as the oleo-resin is brought to boiling point, a thin stream of water is admitted, which considerably reduces the temperature of the still. The water thus is at once converted into steam, which is given off with large volumes of turpentine vapour, and the distillation commences at a much lower

* Gildmeister and Hoffman: "Volatile Oils," page 246.

temperature than the boiling points of the terpenes that constitute the oil of turpentine. This is so, because the temperature of distillation of turpentine oil with steam, (both vapours being saturated), is less than 100° C. This fact was confirmed by an observation of the temperature of distillation carried out at Bhowali. Though the distillation temperature is low, the temperature at which the crude resin is kept at the bottom of the still ranges throughout between 165° C. and 175° C. At the end of the operation, at the same place, when the still was allowed to cool down a little, and the colophony taken out in an open pan, the temperature of the colophony was noticed to be 175°—180° C. It is thus possible that in water distillation colophony undergoes some decomposition towards the later stages of distillation. This supposition was confirmed by observing from time to time the fumes from the charge hole, which at certain stages were found to be distinctly yellow in colour, no doubt due to the decomposition of colophony inside the still. It is thus evident that in the present process unless the temperature inside the still is carefully regulated, there is great danger of the resulting turpentine oil becoming more or less vitiated by the decomposition products of colophony.

In the steam distillation, on the other hand, no great care is needed for the regulation of the temperature, which can easily be controlled, and the decomposition of colophony avoided with greater certainty than in water distillation. In the steam distillation process, large quantities of resin can be handled in a comparatively shorter time, and the rosin obtained is of a lighter colour and better quality.

Thus the process of steam distillation has some advantages over the present process, such as rapidity, facilities in handling large quantities of resin by employing a battery of steam-stills worked by one or two boilers, both for distillation and rectification of the oil, saving in labour and fuel, etc. At the present stage of the turpentine industry in India, the immediate supersession of the latter method by the former may possibly meet with objection, as it has been found practicable to improve the quality of turpentine from Chir resin produced by the present method by redistillation and other means. In addition to this, the adoption of the steam distillation process combined with vacuum distillation and redistillation plant would mean the setting up of distilleries on an entirely

new basis,* requiring the present staff to be strengthened. It is satisfactory to note, however, that the Forest Department both in United Provinces and the Punjab is doing its best to substitute steam distillation for the present method of water distillation, the details of which are not yet to hand. But from the experiments detailed above, it may be remarked here that the improvement of quality of Chir oil, as especially aimed at by means of steam distillation, will be difficult to effect unless the temperature of the still is somehow reduced and the crude oil further rectified by redistillation and by grading the crude product into different qualities. The results of steam distillation on the large scale, for which it is said a plant and process has been perfected in the Punjab, have yet to be tested before this point can be definitely settled.

CHAPTER IV.

(i) Commercial Results that followed the Recommendations made in 1908.

The suggestions at the end of Appendix A were made in 1908, and the partial redistillation of D (or the last fraction of the crude turpentine oil) was thenceforward commenced at the Bhowali Distillery with a view to improve the quality of the oil to the standard of Z (*vide infra*, page 45). But the redistillation of D was unsatisfactory and the oil produced was with difficulty saleable. Mr. E. A. Smythies, Divisional Forest Officer, Naini Tal, writing on 11th November 1909 to the Forest Chemist, complained of this and forwarded three sample bottles of turpentine, one obtained from the North-Western Railway Shops and the other filled with the so-called Z quality, distilled at Bhowali, and the third containing oil which was redistilled under his own supervision.

The commercial opinions received by him on the quality of Z were unfavourable. The Chief Store-keeper, North-Western Rail-

* In this connection, reference may be made to the report of the British Vice-Consul at Hakodate, Japan, where recently it has been proposed to erect a Turpentine Factory. British Consul reports that the Japanese Government has decided to commence the manufacture of turpentine in Karafuto. Machinery for the purpose to the value of £15,300 has been ordered. The sources of the supply of the resin being almost inexhaustible, it is expected more machinery will doubtless be required later. Compared with this it may be stated here that the Departmental Factories in India are in their experimental stage.

way, and Messrs. Turner, Morrison & Co., still complained of its leaving a thick greasy residue. The oil, as obtained under the supervision of Mr. E. A. Smythies, was sent to Messrs. Turner, Morrison & Co., Calcutta, and the Chief Store-keeper, North-Western Railway, Lahore, and the reports received were still unfavourable, though Mr. Smythies was able to sell the whole annual output of this oil.

The three samples sent by Mr. E. A. Smythies to the Forest Research Institute Laboratory, on fractional distillation gave the following results:—

I. Bhowali oil received as marked Z (or $A+B+C+\frac{3}{4}D$)—

160°—167° C.	72·5 per cent.
167°—170° C.	17·5 ,,
Above 170° C.	10·0 ,,

II. The same oil with heavier fractions of D eliminated (prepared by Mr. Smythies)—

160°—167° C.	78 per cent.
167°—170° C.	15·5 ,,
Above 170° C.	6·5 ,,

III. North-Western Railway sample—

150°—155° C.	62·5 per cent.
155°—160° C.	37·5 ,,
Above 160° C.	*Nil*

The sample Z, which the writer experimentally prepared at Bhowali in 1908, had the following fractions as given in Appendix A:—

155°—160° C.	55 per cent.
160°—165° C.	25 ,,
165°—172° C.	11 ,,
Residue above 172° C.	9 ,,

It will be clear from the above figures that the sample Z prepared afterwards at Bhowali for the whole year was not as good, having only 72·5 per cent. passing below 167° C., while the sample originally prepared had 80 per cent. easily passing below 165° C. (*vide* Appendix A). Evidently the control of the process of redistillation was inefficient, as the second sample of Z prepared under

the directions of Mr. Smythies shows distinct improvement, about 78 per cent. passing below 167° C. The latter is nearly equal to the original Z.

It may be remarked here that though the writer of this Note had recommended the manufacture of extra fine oil by redistilling the crude oil to the extent of 80 per cent. and rejecting 20 per cent. of the total output of the crude oil, effect to this recommendation was not given, and so the complaint about the greasy residue left by the oil on evaporation was again received from the purchasers. The oil Z, of course, was naturally not so good as the sample sent by the North-Western Railway, but when Mr. Smythies improved it, as mentioned above, the total annual output of oil of this quality was readily purchased by Messrs. Turner, Morrison & Co., of Calcutta, although the Chief Store-keeper, North-Western Railway, was not prepared to take it. It seems Mr. Smythies had no more trouble in disposing of Z to the Calcutta firm.

In reply to Mr. Smythies' letter to the Institute mentioned above, the crude oil sent by him was rectified by the writer, eliminating 20 per cent. of the heavy turps, which alone caused the greasy residue in the oil on evaporation. The sample of this refined oil was sent to the Chief Store-keeper, North-Western Railway, Lahore, through Mr. Smythies. He approved its quality as suitable for the Railway Workshops.

It follows, therefore, that there would have been no more trouble in disposing of turpentine oil if 20 per cent. of the heavy turps occurring in the crude distillate had been eliminated, as originally proposed. But the loss of oil thus caused is somewhat serious, especially when the turpentine residue left by redistillation had to be thrown away as unsaleable. Even under the partial redistillation that was being done in the distillery, a considerable amount of useless residue of a very heavy nature was gradually accumulating at the factory stores.

(ii) The Utilization of Turpentine Residue in the Manufacture of Printing Ink.

On seeing the nature of the residue, it occurred to the writer that it could be very well utilized in the manufacture of printing

inks. Accordingly about 4 gallons of this residue were sent to Messrs. Butto Kristo Paul & Co., of Calcutta, for trial and valuation. This firm gave the turpentine residue to printing ink manufacturers who reported favourably on it. It is understood that Messrs. Butto Kristo Paul have offered Re. 0-8-0 a gallon f. o. r. Kathgodam for the rejected residue. The price realisable in Calcutta may, perhaps, be taken at about Re. 0-14-0 to Re. 1 a gallon.

Now that the turpentine residue can be utilised and sold in the Calcutta market, the question of the redistillation of the crude turpentine to the extent of 80 per cent. for the preparation of extra fine oil may be worth reconsideration.

Though Mr. Smythies re-opened the question of eliminating the greasy residue from the turpentine oil, the conclusions arrived at in 1908 remained unaltered. The greasy residue is solely due to the heavy turps in the oil produced at Bhowali.

These heavy turps must be eliminated by redistillation in order to free the turpentine oil from the defect, pointed out repeatedly by the purchasers. So far, then, if no changes are to be made in the present plant and in the present process of redistillation, it may be safely asserted that the only way to improve the oil is to thoroughly redistil the whole. This may entail a loss, but in order that the Indian oil may obtain a distinctive name for itself in the market, it is essential that this loss should be incurred reducing the margin of profit.

CHAPTER V.

(i) A New Method for the Distillation of Turpentine Oil with Acetic Acid or Methylated Spirit.

The occurrence of 20 per cent. of heavy turps in the crude oil of turpentine distilled from the resin of *Pinus longifolia* is rather abnormal. This was due to the polymerisation of the original oil in the still under the influence of the high temperature that prevails during distillation, whether conducted by water or by superheated steam. Accordingly, the following two processes were devised for distilling the oil at lower temperatures.

Acetic acid method.—Five hundred grams of the crude resin* were mixed with 100 c.c. of acetic acid. The resin became perfectly liquid on a very gentle warming. It was transferred to the distillation flask and distilled with ordinary steam. The temperature of distillation and of the whole flask was thereby greatly reduced, the distillation taking place below 100° C. The yield of turpentine oil, thus obtained, was 18 per cent. The oil was thoroughly washed with lime water and filtered. It was a crystal clear colourless oil. On fractional distillation it gave the following results:—

Begins to boil	140°—145° C.
Below 160° C.	44 per cent.
Below 167° C. (distilling most of it at 160°—165° C., temperature ris'ng very slowly).	52 ,,
Residue above 167° C.	4 ,,

Thus even the crude oil, obtained by this process, shows 96 per cent. passing below 167° C. This oil, when compared with the crude Bhowali oil, with the same after rectification and with the American oil, shows the following results:—

——	Acetic acid method, crude turpentine.	The crude Bhowali turpentine.	Bhowali oil rectified three times.	The best American oil.
Passing below 165°—167° C.	96%	27·5%	92·5%	97·5—100%
Time of drying when exposed to air on glass surface.	4 hours 4 minutes.	Did not dry within 12 hours.	4 hours 14 minutes.	Traces left undried after 12 hours.
Colophony . .	Pale lemon, transparent bright.	Deep-yellow and dark-yellow.	..	..

This is probably the most satisfactory oil obtained from *Pinus longifolia.* This Laboratory experiment confirmed the view that

* This resin had been lying in the Laboratory stores for some two years.

the heavy turps found in the crude Bhowali oil are solely due to the high temperature employed in distillation.

The colophony obtained was dried over an open fire to drive off all traces of water, free acid, etc. In dried form, it was very transparent, bright and had a fine pale lemon colour. On examination it gave the following constants:—

Acid number	156·65
Saponification number	169·90
Specific gravity	1·082

These constants show the colophony to be of standard quality which does not deteriorate on the addition of acetic acid.

(ii) Recovery of Acetic Acid.

The acetic acid used could be easily recovered from the distillate by first converting it into lime acetate by neutralizing the distillate with lime water, and then distilling the lime acetate with strong sulphuric acid in a special still. The quantity actually recovered from the distillate in the laboratory amounted to 75 per cent. of the total quantity used. Instead of recovering acetic acid from the distillate, it will be a better plan to neutralize the collected watery distillate with soda carbonates and to recover from it the sodium acetate in crystalline form. This by-product could be easily sold at good rates.

A preliminary report on this process and its commercial possibilities was submitted to the President, Forest Research Institute, with a recommendation that the plant used in water distillation at present should be replaced by a battery of copper steam distillation stills tinned inside, connected with a boiler. But as this would have entailed expensive alterations in the existing plant, the proposal of trying the method on a commercial scale was finally given up. Moreover acetic acid would necessarily have some destructive effect on the plant.

Methylated spirit process.—To avoid any changes in the stills at present in use and other disadvantages, instead of acetic acid, methylated spirit was mixed with the crude resin and the latter distilled with steam as mentioned before. Methylated spirit answered the purpose well and the oil obtained was of the same

uniform quality as that distilled through acetic acid, though the colophony was a little less bright and of deeper colour. The process seemed at first sight too costly to be used on a commercial scale. The problem of recovering methylated spirit from the dilute distillate would entail the creation of a separate column still in the turpentine factory, while the addition of methylated spirit, if it were not to be recovered, would make the distillation too expensive. Besides a current of steam would also have to be introduced to distil turpentine oil.

At this stage it struck the writer that instead of distilling turpentine with water, it might be possible to use dilute spirits with some prospect of success without altering the present plant. Thus, though the processes as worked out on a laboratory scale could not be satisfactorily tested on a commercial scale without proper machinery, yet it appeared possible that the methylated spirit process could be adapted to the existing plant without much trouble. This proved to be the case and the yield by this process was 17·6 per cent. The oil was washed with water and filtered. It gave the following results on fractional distillation:—

Begins to boil	140°—145° C.
Below 160° C.	43·3 per cent.
Below 167° C.	53 „

From these figures it is clear that the quality of the oil obtained by both the processes is uniform.

Besides the methylated spirit could be used over and over again in the present method of water distillation, by occasionally increasing its strength by the addition of strong spirit. In the case of steam distillation its use is only possible when a separate still for recovering the spirit is made available.

(iii) Commercial Experiments with Spirit Distillation at Bhowali and Allahabad.

The methylated spirit process was tried on a large scale both at Bhowali and at the Allahabad Exhibition. With 5 gallons of commercial methylated spirit, 50 maunds of crude resin were successfully put through the stills at Bhowali, while at Allahabad with about 3 gallons of spirit about 40 maunds of crude resin was similarly treated. Under continuous working the quantity of methy-

lated spirit required may still not improbably be capable of further reduction. By this process, 100 maunds of resin yield 150 gallons of refined oil, containing 5—6 per cent. of heavy turps, as compared with 136 gallons of turpentine of the Z quality (as obtained by water distillation, eliminating about 7 per cent. of the total crude oil by redistillation), which contains about 15—20 per cent. of heavy turps. But in order to eliminate 5 per cent. of heavy turps from the former, the still must be "cut" when 143 gallons of oil have distilled over from 100 maunds of resin. In the methylated spirit process, there is an increase of 7 gallons of good oil, the value of which covers the additional cost of spirit used. Thus without incurring any additional expenditure, the quality of the oil is greatly improved and if the distillation is carefully carried out, and the still "cut" at the right moment, the oil is practically equal to the American imported oil in its industrial applications.

An objection to the smell of the Indian turpentine oil has at times been urged. This smell is due to the source of the resin being the *Pinus longifolia*. Experiments at Allahabad showed, however, that the smell of the oil could be to a great extent eliminated by washing it either with a 2 per cent. carbonate of soda solution or with lime water, so much so that according to Mr. Smythies' verbal communication to the writer, the representative of Messrs. Turner, Morrison & Co., of Calcutta, who saw the oil being prepared and washed at Allahabad, at once recognised the improvement effected in the odour of the oil.

The process as applied at Bhowali was as follows:—

To a charge of 4 maunds of resin in the still, 3 gallons of 70 per cent. alcohol was added and the distillation carried on over a gentle fire. The distillation was completed in about 3½ hours. The distillate consisted of two layers, the upper one being turpentine and the lower one spirit. The lower distillate containing the spirit was every now and again run out and added to the still till the distillation was complete. The temperature of the crude resin at the bottom of the still, as recorded by the thermometer fitted up inside the still, was below 100° C. for most of the time. Towards the end of operation it rose to 110°—120° C. Thus the spirit distillate is used again and again, its strength being maintained

by the addition of small quantities of fresh spirit. The following table shows how uniform was the quality of the oil obtained:—

No. of harge.	Time of distillation.	Specific gravity by hydrometer.	Fractions taken at Bhowali.	
1	$3\frac{1}{2}$ hours .	·859—·860	155°—160°C.	69%
			160°—165°C	26%
			Residue above 165°C. . . .	5%
2	4 hours .	·859—·860	155°—160° C.	66%
			160°—165°C.	30%
			Residue above 165°C. . . .	4%
3	$5\frac{1}{2}$ hours	·859—·860	155°—160° C.	77·5%
			160°—165° C.	20%
			Residue above 165° C. . . .	2·5%

The oil thus distilled was labelled A.

Attempts were made to reduce the duration of distillation, by dropping spirit from above in a thin stream, as done in the case of water in water distillation, after the still has been heated to about 120° C. by the fire below. The time taken was about $1\frac{1}{2}$ hours from when the destillation started and about 2 hours in all, about $1\frac{1}{2}$ hours less than the time necessary for one charge in water distillation. The oil thus rapidly distilled gave on fractional distillation the following fractions:—

155°—160° C.	38 per cent.
160°—165°C.	48 „
Above 165° C.	14 „

Its specific gravity by hydrometer was ·864—·865.

This shows that oil even when rapidly distilled with 70 per cent. methylated spirit instead of water is in every way better than the Z quality, which is by no means unsaleable. The rapidly distilled oil was labelled B.

As said above it is possible to improve this quality still further by "cutting" the still when 90 per cent. of the oil has come over.

The "cutting" of the still in these experiments, however, was not done. If oil of quality Z meets the trade demand, then it is recommended that this rapid process of spirit distillation should be adopted, as it avoids the partial redistillation.

It was seen that the purity of the oil depended directly on the strength of spirit used, the number of hours taken in distillation, and the temperature. When the spirit became dilute, the temperature of the still rose and the fractions of the oil obtained, passing over below 165° C., ranged from 53 per cent. to 85 per cent.

The following table shows the laboratory results of the examination of seven samples by fractional distillation. These samples were rapidly distilled by the spirit process at Bhowali by the ordinary staff there employed:—

Sample No.	Distilling between 155°—160° C.	Distilling between 160°—165° C.	Residue above 165° C.
1	13%	40%	47%
2	15%	60%	25%
3	13%	45%	42%
4	12%	60%	28%
5	15%	70%	15%
6	15%	65%	20%
7	15%	60%	25%

The above shows the variations in the quality of the oil depending on the strength of the spirit employed, and how necessary it is to keep the spirit of uniform strength.

The samples labelled A and B at the factory were again fractionated at Dehra after about two months. They were kept stored somewhat exposed to the air.

A.

155°—160° C.	. . . .	20 per cent.
160°—165° C.	. . . .	70 ,,
Above 165° C.	. . . .	10 ,,

B.

155°—160° C.	15 per cent.
160°—165° C.	65 „
Above 165° C.	20 „

Sample A that showed at Bhowali about 95 per cent. passing below 165° C. showed only 90 per cent. at Dehra Dun. This may be partly due to the difference between the atmospheric pressure at the two places, which at Bhowali is 25″ and at Dehra 27½″. Besides the oil was exposed for about 15 days to the air at Bhowali before packing, and at Dehra for about a month in the half empty canisters in which it was kept.

It seems that the Indian oil distilled from Chir resin is liable to rapid polymerisation if air is not excluded as soon as it is distilled, washed and filtered. The time allowed between the first distillation and final packing should be reduced to a minimum.

The experiments conducted at Bhowali on a fairly large scale indicate the advantages of working with the methylated spirit process, always provided that great care is taken to distil slowly and to keep up the original strength of the spirit used, otherwise, as shown above, the results are somewhat indifferent though they **are always better** than in the case of water distillation.

(iv) Summary of Results obtained.

From the Laboratory experiments, it is clear—

(1) That the oil as it occurs in the oleo-resin is of much better quality than that usually produced by water distillation, which has necessarily to be carried out at high temperatures, but it is liable to a greater amount of polymerisation under the influence of high temperature and aërial oxidation, and that the 20 per cent. of the heavy turps occurring in the water distilled crude oil are due to the decomposition that takes place in the process of distillation.

(2) That oil of the best and of a uniform quality can be obtained by one distillation only, if the acetic acid or methylated spirit method be combined with simple

steam distillation, taking care that the still is " cut " at the right moment.

(3) That the above results could be obtained by using methylated spirit in the existing water distillation plant, provided that the distillation is carried on slowly and with care.

(4) That the distillation of turpentine with 70 per cent. of spirit always gives better results than water distillation.

(5) That to reduce the strong and unpleasant resinous smell of the oil, it should be washed with either lime water or 2 per cent. soda carbonate solution. Besides rendering the smell less acute, the washing removes traces of rosin that the oil might contain.

CHAPTER VI.

Commercial Opinions on the Spirit-distilled Oil.

The oil labelled A was sent to the Chief Store-keeper, North-Western Railway, and the Chief Store-keeper, Bengal-Nagpur Railway, and the reports received from them were indifferent classifying it as second class fit only for rough work. But it was afterwards found out that the oil of quality A would be suitable for all kinds of railway works (*vide* Appendix B).

The sample A was also sent to Messrs. Butto Kristo Paul & Co., of Calcutta, by the writer, who replied as follows :—

> " In further continuation of our previous letter in reply to yours, No. 656/99, we beg to inform you that the samples of turpentine and rosin sent by you are approved by the experts of our firm. We are sorry not to have any information about the total output of the same articles, as solicited in our last letter. However, we believe we shall be able to sell all the output of your factory."

From a subsequent communication from the same firm the writer understands that they can dispose of the spirit distilled oil at about

annas 2 a gallon less than the current rates of imported turpentine in Calcutta.

The Reporter on Economic Products to the Government of India, Calcutta, in his letter No. 1297, dated 13th September 1910, to the Assistant Conservator of Forests, Naini Tal Division, reports on this sample as follows :—

> "The oil is clear and almost colourless, with a characteristic odour. The specific gravity at 15° C. is 0·867, and the initial boiling point is 163° C. The greater part of the oil distils below 179° C. There is only 0·59 per cent. of solid matter left on evaporation, and the acidity is equal to 0·035 per cent. of acetic acid. This is a very good sample of turpentine oil, the best I have examined from Naini Tal."

This temperature of 179° C. is at variance with those many times determined both at Bhowali and at Dehra. The difference is more than what can be attributed to the form of distillation flask, variations of thermometers, barometric pressure, the rate of distillation, etc. The spirit distilled crude oil A was sent by the writer to Dr. J. W. Leather, Imperial Agricultural Chemist, Pusa, to see whether the results of distillation at Pusa differed in any way from those obtained at Dehra Dun. Together with A, two other samples marked B and C (B being A^1 or redistilled A mentioned in Appendix B and C being $A^1 + B^1 + C^1 + D^1$ mentioned in Appendix B) were also sent. These three samples were received from Bhowali three months after distillation; it is, however, doubtful whether they were the best samples obtainable. This might have been due to over-exposure to air, incidental mixture of rosin, confusion of inferior samples distilled experimentally with spirits, with the superior samples in the factory stores, because on fractional distillation A gave only about 80—85 per cent. distilling below 167° C. and B gave only 95 per cent. distilling below 167° C., and C 90 per cent.

Copy of Dr. Leather's letter No. 457/18-2 of 1910, dated 23rd November 1910.

"With reference to the three samples of turpentine, A, B and C, which you sent with your letter No. 687/99, dated 20th September

last, I have now the honour to intimate to you the temperatures of distillation.

" 'A' commenced to boil at 158° C.; the distillation was stopped at 172° C. when 88 per cent. had passed over.

" 'B' commenced to boil at 162° C.; it was stopped at 166° C. when 98 per cent. was found to have distilled over.

" 'C' commenced to boil at 158° C.; it was stopped at 169° C. when 94 per cent. had distilled over.

" The atmospheric pressure whilst working varied from 29·7 to 29·9 inches. The effect of a reduction of pressure of two inches was found to vary from 3° to 4°, and was the same for all the three samples. You will see from a comparison of these data with those which you mentioned in your letter, that the difference of elevation between here and Dehra Dun accounts for practically the whole of the difference between the observed temperatures."

Therefore, the variance between the figures of the writer and those recorded by the Reporter on Economic Products to the Government of India is partly due to the difference in the conditions of fractional distillation and partly to the variations in the quality of the spirit distilled oil, which was only experimentally produced at Bhowali, little care being taken to produce a large sample of uniform quality.

The Superintendent, Assam-Bengal Railway, Pahartali, writing to Mr. Smythies, expresses the following opinion about the spirit distilled oil :—

> " I have the honour to inform you that I have had the sample of turpentine supplied by your Forest Ranger tested, and the Locomotive Superintendent of this Railway reports that it is of good quality, but the difference in freight from the station of delivery to Chittagong on the turpentine obtained from Calcutta at Rs. 2-12 per gallon and that offered by your Department at Kathgodam at Rs. 2-8 per gallon makes the latter comparatively costly, and I am, therefore, unable to adopt it for use on this Railway."

The samples A (being oil slowly distilled with spirit) and B (being oil rapidly distilled with spirit) were sent by the Divisional Forest

Officer, Naini Tal, to the Imperial Institute, London, for examination, and the second report given in Appendix D embodies the results obtained. As pointed out in Chapters II and V, the Forest Chemist has noticed a distinct improvement in the quality of the oil by distilling it with methylated spirit, and accordingly he sent two more samples of both the crude and the rectified oil obtained by distillation with acetic acid in the Laboratory to make sure that the samples A and B sent from the factory were not mixed up with inferior oils produced with dilute spirit as mentioned above. The third report in Appendix D gives the results of the examination of these two samples as compared with those of A and B. Excepting slight differences that are natural in oils derived from different lots of crude resin, the report shows the general composition of the Laboratory samples to be similar to those made at the distillery. The spirit distilled oil rectified by redistillation and by the elimination of 5 per cent. of the total crude oil is, as will be evident from the report, richer in lighter terpenes. Because of the different conditions under which fractional distillation was carried out at the Imperial Institute it is not possible to compare the figures as obtained there with those obtained at Dehra or Pusa. But taking the figures worked out at the Imperial Institute as they are, it will be seen that only 33 per cent. of the total crude oil distilled with water passed at low temperatures (*vide* first report, Appendix D), about 66 per cent. passing above 173° C., while the crude spirit distilled oil had 79—83 per cent. passing below 175° C. (*vide* second report, Appendix D), and the redistilled spirit distilled oil gave 89 per cent. passing below 175° C. These figures also conclusively show the improvement in quality that is effected by carrying the distillation at low temperatures with methylated spirit. No figures are available from the Imperial Institute allowing of comparison between the spirit or acetic acid distilled oil and the crude or rectified water-distilled oil, yet the figures obtained at Dehra leave no doubt that the quality of the former is considerably purer.

The report says that though the solvent power is inferior to the best oil obtainable in England, yet it can be used quite well for varnish making.

Professor Dunstan recommends that trials of the process proposed should be made at the distillery to decide whether the

improvement in the oil repays the extra cost of using methylated spirit.

CHAPTER VII.

General Directions for Turpentine Distillation.

(1) It is essential for the production of good turpentine oil and rosin to "cut" the still when about 90 per cent. of the total calculated quantity of oil has passed over, in case the method of spirit or acetic acid distillation is adopted. If not, the still should be "cut" when 80—85 per cent. of the total calculated oil has distilled over.

(2) When resin is distilled under high temperatures, a good deal of resinous matter is carried along mechanically with the distilling vapours, and is deposited in a solid form in the delivery pipes, and this slowly getting dissolved in the turpentine oil vitiates the quality of the latter. This can be avoided by carrying on the distillation slowly at low temperatures, and by fitting a dome-shaped lid to the still instead of the flat one as in use at present at Bhowali.

(3) To reduce the unpleasant pine and naphthic odour, the oil should be washed with lime water or with 2 per cent. carbonate of soda solution, in closed washing cylindrical cisterns fitted with stirring appliances, stop-cocks and gauge glasses.

(4) The oil should never be allowed to remain long exposed to the action of moisture and air. After it is washed it should be immediately filtered and sealed in clean new canisters. It is preferable to have some automatic arrangement for filling the canisters, air having been previously excluded.

(5) The open-mouthed copper cylinders, that are at present being used for the collection of distilled turpentine, should give place to closed cylindrical vessels with gauge glasses, marked at definite points for the workman to judge if the requisite quantity of turpentine oil has distilled over. On seeing the oil reach the mark he should remove the vessel.

(6) Too much care can scarcely be exercised in distillation operations, in washing, in packing, and in seeing that the turpentine does

not come in contact with the air. The presence of resinous impurities and any considerable contact with the air will alter the fractions of the oil.

(7) Before the oil is sent to the market it should be properly examined. A good rectified Indian turpentine oil should answer the following tests:—

(*i*) Sp. gr. at 20° C.	0·860—0·864
(*ii*) Parts of 90 per cent. alcohol required by one part of turpentine to effect solution	7—7·2

(*iii*) 10 c.c. of the oil put on clean glass surface should completely evaporate in 24 hours in the shade and in 8—9 hours in the sun, leaving no residue or at the most a thin sticky film, due to oxidation.

(*iv*) When applied with a brush on a clean glass surface 6″ × 4″ and exposed to sun, it should dry in about 15 minutes, leaving no greasy residue nor a sticky surface. This test is very simple, but care must be taken that the finger used to judge the surface is perfectly dry and free from resinous or greasy feel.

Some merchants prefer to dip a piece of clean white paper in turpentine oil and see the nature of the stain left by it. A good turpentine oil should leave no trace of any oily stain. It should dry clean in a few minutes.

(*v*) When shaken with 5 per cent. caustic soda solution, it should give no coloured under-layer nor a milky layer. This test is useful in detecting if any rosin has distilled over and dissolved in the turpentine.

(*vi*) It should, on fractional distillation, wholly or almost wholly distil over under 170° C. at a barometric pressure of 25″—27″, in an ordinary fractional distillation flask.

(*vii*) It is essential that in the distillation of *Pinus longifolia* resin the distillation temperature and the temperature of the resin during distillation be kept as low as possible. The best method of distillation, therefore, will be superheated steam distillation *in vacuo* with or without the addition of a little methylated spirit; a suitable apparatus would be some form of the ordinary vacuum still fitted with steam pipes and modern types of double-surfaced condensers; at the same time there appears to be no reason why the process of simple steam distillation with the addition of methylated spirit to the crude resin should not answer well. In either case the distillery should have a separate still for the recovery of spirit from the distillate.

Should the above be not easily available spirit distillation carried out on the same lines as water distillation will give nearly as satisfactory results. But the form of the still should be globular, and the delivery pipe should be so placed as to prevent the resinous impurities from mechanically passing over into the distillate.

(*viii*) In the first distillation of the crude resin, in spite of all precautions taken, the admixture of resinous impurities with the oil distilled can scarcely be wholly avoided, as it will be evident from the behaviour of oil when stored in glass bottles for $1\frac{1}{2}$ years, as mentioned in Chapter II, page 13. For making oil of a uniformly standard quality, it is recommended that the oil should be rectified by redistillation in every case, till most of it passes below 167°—170° C. and answers the tests given above.

APPENDIX A.

(i) Details of Redistillation Experiments carried out to improve the Quality of the Oil obtained by Water Distillation in the year 1908.

I.

The usual charge at Bhowali distillery is 300 lbs. of the crude oleo-resin or 9 tins, which yields 57 lbs. of the oil which is collected in glass bottles of which 41—43 per charge are obtained. Thinking that the heavier portions of the turpentine oil will naturally distil last, Mr. P. H. Clutterbuck divided the distillate into four fractions, the first three of ten bottles each and making about 15 lbs. each by weight, the fourth fraction being the last 13 bottles of about 18 lbs. These four fractions were received in the Laboratory of the Forest Research Institute with the following labels:—

A denotes first 10 bottles of charge distilled under ordinary circumstances.

B denotes second 10 bottles of charge distilled under ordinary circumstances.

C denotes third 10 bottles of charge distilled under ordinary circumstances.

D denotes the balance (13 bottles) of charge distilled under ordinary circumstances.

The following table shows their general character:—

TABLE I.

——	A	B	C	D
160°—165° C. . .	50·0%	50·0%	47·5%	*Nil*
165°—172° C. . .	33·5%	33·0%	31·5%	27·5%
172°—180° C. . .	8·5%	7·0%	10·0%	32·0%
180°—200° C. . .	4·0%	5·0%	5·5%	11·5%
Residue above 200° C. .	4·0%	5·0%	5·5%	29·0%
Specific gravity at 30° C..	0·859	0·861	0·864	0·883
Acid number . .	1·95	1·95	1·95	7·29

Of the fractions A and B 83 per cent. and of C 79 per cent. passes below 172° C., the residue above 200° C. is between 3·5 per cent., and the specific gravity of these fractions is 0·859—0·864. It will be seen that A is the lightest, then comes B and then C. The acidity of A, B, C is only a trace. The fraction D on the other hand is abnormally heavy. Only 27 per cent. of D passes below 172° C. The specific gravity is greater being 0·883 and acidity is seven times that of A, B, C. If D is eliminated, the oil A, B, C will be much finer. So A, B, C were mixed and fractionated.

Fractions of A+B+C.

160°—165° C.	45	per cent.
165°—172° C.	30	,,
172°—180° C.	7·5	,,
180°—200° C.	5·0	,,
Residue above 200° C.	12·5	,,

It will be seen that when A, B and C are mixed in equal proportions, a sample is obtained of which 75 per cent. passes below 172° C. and 82·5 per cent. below 180° C. A turpentine oil passing between 160°—180° C. cannot but be regarded as quite above the average. Even if no redistillation is done, this sample might claim distinct preference over many of the market turpentines.

II.

The fractions A, B, C, D were thoroughly washed with water and the samples A_1, B_1, C_1, D_1 were made:—

A_1 denotes first 10 bottles of a charge distilled under ordinary circumstances but shaken thoroughly with water.

B_1 denotes second 10 bottles of a charge distilled under ordinary circumstances but shaken thoroughly with water.

C_1 denotes third 10 bottles of a charge distilled under ordinary circumstances but shaken thoroughly with water.

D_1 denotes balance (13 bottles) of a charge distilled under ordinary circumstances but shaken thoroughly with water.

The following table gives the results of their examination:—

TABLE II.

—	A_1	B_1	C_1	D_1
160°—165° C. . .	69·0%	60·0%	41·0%	*Nil*
165°—172°C. . . .	18·0%	22·5%	38·5%	25·5%
172°—180° C. . .	5·0%	9·0%	11·5%	28·5%
180°—200° C. . .	3·5%	3·5%	5·5%	20·5%
Residue above 200° C. .	4·5%	5·0%	3·5%	25·5%
Specific gravity at 30° C. .	0·858	0·861	0·869	0·880
Acid number . . .	1·63	1·95	1·61	5·05

It will be seen that A_1, B_1, C_1, D_1 have the same amount, *viz.*, 79—83 per cent. passing below 172° C. The general character of the fractions remains the same. There is no doubt that washing is very useful in removing the acidity of the oil and consequently the acidity of fractions has decreased a little. The specific gravity of D has been reduced from 0·883 to 0·880.

III.

Thinking that slow distillation might give a better quality of the oil, the stills were only charged twice in 24 hours, each operation lasting $5\frac{1}{2}$ hours as against $3\frac{1}{2}$ previously, and the distillate was fractionated as above:—

A_2 denotes first 10 bottles of a charge (when only two charges were made in the day, each charge lasting about $5\frac{1}{2}$ hours against 3 to $3\frac{1}{2}$ hours under ordinary circumstances).

B_2 denotes second 10 bottles of a charge (when only two charges were made in the day, each charge lasting about $5\frac{1}{2}$ hours against 3 to $3\frac{1}{2}$ hours under ordinary circumstances).

C_2 denotes third 10 bottles of a charge (when only two charges were made in the day, each charge lasting about $5\frac{1}{2}$ hours against 3 to $3\frac{1}{2}$ hours under ordinary circumstances).

D_2 denotes balance (12 bottles) of a charge (when only two charges were made in the day, each charge lasting about $5\frac{1}{2}$ hours against 3 to $3\frac{1}{2}$ hours under ordinary circumstances).

The following table gives the results of the examination of their fractions :—

TABLE III.

——	A_2	B_2	C_2	D_2
160°—165° C. . .	70·5%	65·0%	58·5%	*Nil*
165°—172° C. . .	16·5%	20·0%	24·0%	20·0%
172°—180° C. . .	8·0%	6·5%	7·5%	35·0%
180°—200° C. . .	*Nil*	2·5%	3·5%	14·0%
Residue above 200° C. .	5·0%	6·0%	6·5%	31·0%
Specific gravity at 30° C..	0·862	0·865	0·868	0·878
Acid number . . .	1·29	1·29	1·29	1·59

It will be seen that A_2, B_2, C_2 have slightly improved and now 82—86 per cent. instead of 79—83 per cent. of their fractions passes below 172° C. The residue above 200° C. practically is the same. The specific gravity is normal, that of D_2 being much less, 0·878 instead of 0·880—0·883 as in 1 and 2. The acidity of all the four fractions has become only a trace. In this too D, however, is as bad as before. Only 20 per cent. of D passes below 172° C. The residue above 200° C. of D is 31 per cent. as against 5—6 per cent. of the first three fractions.

Slow distillation is evidently better than rapid distillation (for other reason see page 53).

IV.

The oil distilled as in III, but washed with water:—

A_3 denotes first 10 bottles of a charge distilled under circumstances as explained under A_2 but shaken with water.

B_3 denotes second 10 bottles of a charge distilled under circumstances as explained under A_2 but shaken with water.

C_3 denotes third 10 bottles of a charge distilled under circumstances as explained under A_2 but shaken with water.

D_3 denotes balance (12 bottles) of a charge distilled under circumstances as explained under A_2 but shaken with water.

The following table gives the results of examination:—

TABLE IV.

—	A_3	B_3	C_3	D_3
160°—165° C. . .	79·5%	58·0%	42·0%	*Nil*
165°—172° C. . .	13·0%	28·5%	32·5%	21·0%
172°—180° C. . .	4·0%	8·0%	15·5%	23·5%
180°—200° C. . .	*Nil*	*Nil*	*Nil*	24·0%
Residue above 200° C. .	3·5%	5·5%	10·0%	31·5%
Specific gravity at 30° C. .	0·858	0·861	0·863	0·883
Acid number . . .	1·30	0·97	0·97	3·48

By washing, the fractions passing below 172° C. are practically the same, the residue above 200° C. is the same, acidity is slightly decreased, D excepted. The specific gravity too has decreased a little. But D is as heavy as before.

In the Laboratory A, B, C, D were now mixed to examine the quality of the mixture, which on fractional distillation gave the following results:—

A + B + C + D in equal proportions.

Passing below 172° C.	67	per cent.
„ „ 172°—180° C.	13·5	„
„ „ 180°—200° C.	9·0	„
Residue above 200° C.	10·5	„

Here we may appropriately give the results of the examination of the original oil as manufactured at Bhowali:—

A_4 denotes the present Bhowali turpentine but shaken with water.

B_4 denotes the present Bhowali turpentine.

TABLE V.

—	A_4	B_4
160°—165° C.	27·5%	*Nil*
165°—172° C.	32·5%	47·5%
172°—180° C.	17·5%	21·0%
180°—200° C.	9·0%	14·0%
Residue above 200° C.	13·5%	17·5%
Specific gravity at 30° C.	0·869	0·872
Acid number	3·21	5·13

It will be seen that A + B + C + D is better than A_4 and B_4. Only 60 per cent. of A_4 passes below 172° C., while of A + B + C + D 67 per cent. passes below that temperature. The residue of the latter is only 10 per cent. while of the former is 14—18 per cent.

V.

D forming the 12 last bottles of the distillate was collected bottle by bottle, that is, in fractions of about $1\frac{1}{2}$ lbs. each, and 12 samples were received from Naini Tal with the following labels:—

1	represents	31st	bottle	distilled.
2	,,	32nd	,,	,,
3	,,	33rd	,,	,,
4	,,	34th	,,	,,
5	,,	35th	,,	,,
6	,,	36th	,,	,,
7	,,	37th	,,	,,
8	,,	38th	,,	,,
9	,,	39th	,,	,,
10	,,	40th	,,	,,
11	,,	41st	,,	,,
12	,,	42nd	,,	,,

The results of their examination are tabulated below:—

TABLE VI.

—	1	2	3	4	5	6	7	8	9	10	11	12
160°—165° C.	35·0%	28·0%	18·0%	12·5%	11·0%	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*
165°—172° C.	29·5%	35·0%	34·5%	32·0%	37·0%	36·0%	30·0%	7·0%	*Nil*	*Nil*	*Nil*	*Nil*
172°—180° C.	18·5%	16·5%	23·5%	23·0%	19·5%	28·0%	25·0%	16·5%	10·0%	16·5%	10·0%	11·0%
180°—200° C.	5·5%	8·0%	10·0%	11·0%	14·5%	13·0%	14·0%	38·0%	15·0%	25·0%	5·0%	18·5%
Residue above 200° C.	11·5%	12·5%	14·0%	21·5%	18·0%	23·0%	31·0%	38·5%	75·0%	58·5%	85·0%	70·5%
Specific gravity at 30° C.	0·874	0·866	0·881	0·874	0·878	0·879	0·886	0·903	0·909	0·910	0·917	0·907
Acid number	4·63	3·23	3·81	3·84	3·89	6·37	5·37	9·30	9·36	11·06	14·45	11·10

It will be seen that the first five bottles go on diminishing in their first fractions passing below 165° C. from 35·0 to 11·0 per cent., 44 to 63 passes below 172° C., the residue is 11—21 per cent. Hence a fraction made by mixing No. 1 to No. 5 will be better than D. Accordingly a mixture in equal proportion of No. 1 to No. 5 was made and fractionated with the following results:—

Fractions of 1+2+3+4+5 mixed in equal proportions.

Up to 172° C.	45 per cent.
172°—180° C.	25 ,,
180°—200° C.	15 ,,
Residue	15 ,,

This mixture was added to A+B+C in equal proportions and fractionated with the following results:—

160°—165° C.	42·5 per cent.
165°—172° C.	20·0 ,,
172°—180° C.	17·5 ,,
180°—200° C.	9·0 ,,
Residue	11·0 ,,

It will be seen from the above figures that the first five bottles of D are good and if mixed with A+B+C they do not vitiate the quality of the resultant oil to any great extent. A+B+C has 82·5 per cent. passing below 180° C., while A+B+C+ (1+2+3+4+5) has 78·5 per cent. This when compared with the oil, which is at present being sent to market, stands thus:—

TABLE VII.

Sample.	Passing below 172° C.	Passing below 180° C.
A_4 (the oil at present sent to market)	60·0%	77·5%
A+B+C	75·0%	82·5%
A+B+C+(1+2+3+4+5)	62·5%	80·0%

Therefore, if A + B + C are increased by the addition of 1, 2, 3, 4 and 5 from every charge, the sample will be nearly quite as good as A + B + C alone.

Experiments at Bhowali Distillery.

The results given above clearly show that if the crude turpentine oil is divided into four fractions as was done by Mr. P. H. Clutterbuck, then the first three fractions will prove to be fairly good samples of turpentine oil, and the fourth fraction D needs further treatment.

VI.

Redistillation of D.

Accordingly, D was redistilled in a small copper still of the same form as is in use for the distillation of crude turpentine on exactly the same lines on which crude turpentine is distilled. A heavy coloured, viscous residue was left behind, and out of 10 bottles (*i.e.*, about 15 lbs.), $7\frac{1}{2}$ bottles (*i.e.*, 11 lbs.) were recovered. This means that by redistilling it 75 per cent. is recovered and 25 per cent. is left as a heavy residue.

The redistilled D on fractional distillation gave the following fractions:—

155°—160° C.	27·5 per cent.
160°—165° C.	51·5 ,,
165°—172° C.	12·5 ,,
Residue	8·5 ,,

The fraction of residue from the redistilled D gave the following fractions, which have very high boiling points and seem to be complex resinous acids mixed with the decomposition products of colophony:—

230°—240° C.	23·5 per cent.
240°—245° C.	46·0 ,,
245°—250° C.	11·0 ,,
A residue highly coloured semi-solid, viscous mass	19·5 ,,

It is evident now that this fraction being mixed with A, B, C not only raises their boiling points, but vitiates the quality of the oil as a whole, reduces its drying quality, and it is probable that

this portion of D if allowed to remain in contact with the rest of the oil would hasten the oxidation of the oil when stored and increase its acidity.

The redistilled D was mixed with A, B and C in proportion of $\frac{3}{4}$ D + A + B + C, and the sample thus prepared was fractionated.

Fractions of $A+B+C+\frac{3}{4}$ *redistilled D or Z.*

155°—160° C.	55 per cent.
160°—165° C.	25 „
165°—172° C.	11 „
Above 172° C. residue	9 „

This oil Z, therefore, has 91 per cent· passing below 172° C. In the preparation of this oil there is a loss of only 6·25 per cent.

D put back into the crude turpentine.

Instead of redistilling D, it was proposed to put D back again into the still and the turpentine was divided into five fractions as follows:—

(*a*) First 10 bottles.
(*b*) Second 10 bottles.
(*c*) Third 10 bottles.
(*d*) Fourth 10 bottles.
(*e*) The last 4 bottles.

The results of fractionation of the fractions are given in the following table:—

TABLE VIII.

Boiling between	(*a*)	(*b*)	(*c*)	(*d*)
155°—160° C. . .	55·0%	44·0%	40·0%	22·0%
160°—165° C. . .	20·0%	30·0%	35·0%	33·5%
165°—172° C. . .	12·5%	12·0%	12·0%	18·5%
172°—180° C. . .	2·5%	4·0%	5·5%	10·0%
Residue above 180° C. .	10·0%	10·0%	7·5%	16·0%

The fractions of (*e*) are—

155°—160° C.	Nil
160°—165° C.	11·0 per cent.
165°—172° C.	11·0 „
172°—180° C.	20·0 „
180°—200° C.	20·0 „
Above 200° C.	38·0 „

Thus (*a*) has 87·5 per cent., (*b*) has 79·0 per cent., (*c*) has 80·0 per cent. and (*d*) has 65·0 per cent. passing below 172° C., while (*e*) has only 22 per cent. Out of these, another sample was prepared by mixing (*a*), (*b*), (*c*) and (*d*) and fractionated with the following results:—

$(a)+(b)+(c)+(d)$.

155°—160° C.	43·0 per cent.
160°—165° C.	27·5 „
165°—172° C.	15·0 „
Residue above 172° C.	14·5 „

$(a)+(b)+(c)+(d)$ has thus about 86 per cent. passing below 172° C., which, in the writer's opinion, makes it a very good sample of turpentine oil.

It may be remarked here that the heavy portions contained in D instead of being eliminated must necessarily have mixed with the colophony, and the residual balance (*e*) must, therefore, be put back into the still with the fresh charge. As the quantity of (*e*) that mixes with the colophony in the still is very small, the quality of colophony is not in any way vitiated. But knowing the extremely heavy nature of the residue of the fraction D, it is preferable to altogether eliminate it. Besides $(a)+(b)+(c)+(d)$ is slightly lower in the percentage of its low boiling fractions than Z; therefore, we may say that instead of putting back the heavy fraction of D or (*e*) into the still, it is better to redistil D and prepare the sample Z instead of $(a)+(b)+(c)+(d)$.

It was proposed to investigate the difference between Z and redistilled A + B + C + D and accordingly the whole of the crude oil was redistilled on exactly the same lines as crude resin. Thirty gallons of the crude oil were redistilled and 28 gallons were recovered. Twenty-eight gallons made 180 bottles of the size used in the factory,

which were divided into nine fractions of 20 bottles each, *i.e.*, of about 30 lbs., the first fraction being the first 20, the second fraction the second 20 bottles, and so on.

They were all fractionated with the results tabulated below:—

TABLE IX.

Distilling between	1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	9th.
155°—160° C. .	80·0%	77·5%	70·0%	72·0%	61·0%	55·0%	33·0%	*Nil*	*Nil*
160°—165° C. .	15·0%	19·0%	22·5%	21·0%	22·5%	35·0%	40·0%	20·0%	*Nil*
165°—172° C. .	5·0%	3·5%	7·5%	7·0%	16·5%	10·0%	14·5%	25·0%	*Nil*
172°—180° C. .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	12·5%	20·0%	*Nil*
180°—200° C. .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	10·0%	*Nil*
Residue 200° C.	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	25·0%	*Nil*
200°—215° C. .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	20·0%
Above 240° C. .	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	*Nil*	80·0%

It will be noticed that the first seven fractions have 80—33 per cent. of turpentine oil passing below 160° C., which was not the case in the fractionation of A, B and C. It will be seen that 95—73 per cent. of the best seven fractions passes below 165° C., and 100—88 per cent. passing below 172° C. Only the 8th and 9th fractions are comparatively very heavy. Of the 8th fraction, only 45 per cent. passes below 172° C. and 20 per cent. passes below 172°—180 ° C., with a residue of 25 per cent. above 200° C., while the 9th fraction begins to distil only above 200° C. giving 20 per cent. below 215° C. and a residue of 80 per cent. above 200° C. Evidently the 9th fraction should be separated from the good oil.

In order to test the quality of the redistilled A+B+C+D, all the nine fractions were mixed up and the homogeneous mixture fractionated.

Redistilled A+B+C+D including the last or the 9th fraction.
(Redistillation done in an old still.)

155°—160° C.	40·0 per cent.
160°—165° C.	29·0 „
165°—172° C.	14·0 „
Above 172° C.	17·0 „

In this case, the loss calculated is only about 6 per cent.

Redistilled oil with its fractions mixed up excluding the last nine bottles

155°—160° C.	45·0 per cent.
160°—165° C.	32·0 „
165°—172° C.	11·0 „
Residue above 172° C.	12·0 „

The loss calculated in this case is about 11 per cent.

From the above table it will be seen that the redistilled oil, when the last portion of the distillate is not included, gives about 80 per cent. below 172° C., which nearly equals the quality of Z with the difference that the loss entailed in the distillation of the whole quantity is 11 per cent., while redistilling D alone the loss is only about 6·5 per cent. But this operation of redistillation of A + B + C + D was done in the still used for the distillation of crude turpentine, which was coated inside with a layer of colophony, and, therefore, these results are probably wanting in accuracy, as the presence of colophony in the still must have probably allowed the heavier portions of the oil to distil over and mix with the distillate. These results were apparently inaccurate because redistillation of all the fractions mixed together must give a better oil than Z in whose case only a portion of the whole was redistilled. Before saying, therefore, that from a practical commercial point of view it would be unnecessary to redistil the whole quantity when the redistillation of a small portion of the oil would give the same quality of the refined oil, it was thought necessary to see if the redistillation of A + B + C + D in a perfectly new still would give much better results than when only D is redistilled. Accordingly a quantity of A + B + C + D was redistilled in a new still and the redistilled oil was fractionated with the following results:—

Redistillation of A + B + C + D in a new still.

155°—165° C.	80·0 per cent.
165°—172° C.	15·0 „
Residue above 172° C..	5·0 „

This shows that the redistillation should always be done in a separate still maintained for the redistillation of the oil alone, and not repeated in the still used for the crude resin.

The quality of the redistilled oil is, therefore, as it ought to be, better than Z when only D is redistilled and is of the same quality as the redistilled oil obtained by steam distillation. Z has only 80 per cent. passing below 165° C. and 91 per cent. passing below 172° C. and a residue of 9 per cent. above 172° C., while on redistillation A + B + C + D has 80 per cent. passing below 165° C. and 95 per cent. passing below 172° C and a residue of 5 per cent. above 172° C. It may be remarked here that the oil can be further improved if subjected to further redistillation. But the repetition of the process of redistillation would entail a loss of 6—8 per cent. every time and thus an oil redistilled thrice though exceptionally pure, mostly passing below 165° C., would have lost 20 per cent. in weight. For the present, therefore, to refine our oil above this quality will not be advisable from a commercial point of view until the prices offered warrant such rectification, or any further difficulty arises in its disposal.

Extra fine oil.

A sample of redistilled A + B + C + D was subjected again to redistillation in the Laboratory and an extra pure oil was obtained. On fractional distillation it gave the following fractions:—

155°—163° C.	55·0 per cent.
163°—165° C.	37·5 „
165°—172° C.	7·5 „
No residue.	

(ii) Redistilled Indian Turpentine compared with the Commercial Oils.

The redistilled turpentine oil, it may be urged now, is decidedly superior to the turpentine available in the local markets. It may be mentioned here that two samples of good turpentine were obtained from Messrs. Fitch & Co., Chemists, Dehra Dun, one labelled as "rectified for internal use" and the other "commercial spirits

of turpentine." Both of them were fractionated with the following results:—

TABLE X.

Distilling between	Rectified spirit of turpentine.	Commercial spirit of turpentine.
160°—165° C.	23·0%	16·5%
165°—172° C.	16·0%	15·5%
172°—180 °C.	16·0%	12·0%
180°—200° C.	36·0%	16·0%
Above 200° C.	9·0%	40·0%

The rectified oil for internal use showed only 23 per cent. passing below 165° C. and 39 per cent. passing below 172° C. and 55 per cent. only passing below 180° C. The test of a good oil according to the British Pharmacopœia is that it should all distil between 160°—180° C.

The "commercial spirit of turpentine" has only 16·5 per cent. passing below 165° C. and 32 per cent. passing below 172° C. The latter leaves a residue of 40 per cent. above 200° C.

Another very good sample obtained from a Dehra Dun druggist under the name of French oil of turpentine gave the following fractions:—

150°—155° C.	71·0 per cent.
155°—163° C.	13·5 ,,
163°—172° C.	13·5 ,,
Residue above 172° C.	2·0 ,,

It may be remarked here that the French oil is the highest quality of turpentine available in the world's market and is known to wholly distil between 155°—163° C. This sample of the French turpentine, however, has 84·5 per cent. passing below 163° C. and our redistilled oil has 80 per cent. passing nearly below the same temperature.

Other bazar samples of turpentine were found to be adulterated with petroleum and were useless for purposes of comparison.

The Bhowali redistilled oil and American oil obtained from Messrs. Turner, Morrison & Co., Calcutta, compared.

A small quantity of the best American turpentine available was obtained from Messrs. Turner, Morrison & Co., Calcutta. The oil supplied had a pale yellow colour and a slightly rancid smell. On fractional distillation it readily all distilled over below 163° C.:—

150°—155° C.	70·0 per cent.
155°—163° C.	27·0 „
Residue above 163° C.	2·5 „

Taking this oil as supplied by Messrs. Turner, Morrison & Co. as standard American turpentine oil, it compares with the redistilled oil and Z in the following table:—

TABLE XI.

——	The Bhowali crude oil.	Z mark Bhowali oil.	Redistilled oil.	Bhowali extra fine.	American turpentine oil (as obtained from Messrs. Turner, Morrison & Co., Calcutta).
Passing below—					
155°—165° C. .	27·5%	80·0%	80·0%	92·5%	100%
172° C. . . .	60·0%	91·0%	95·0%	100·0%	. .
Acid number .	3·21	*Nil*	0·89	*Nil*	3·36
Specific gravity at 22° C.	0·869	. .	0·8635	. .	0·864
Parts of 90 per cent. alcohol required by 1 part of turpentine to effect solution.	8—9	. .	7—7·2	. .	6

From the above table it is clear that the redistilled Bhowali oil is good for all practical purposes, and Bhowali "extra fine" is quite as good in all respects as the American oil as imported to this country in its application in the paint and varnish industries.

(iii) General Results reported in the year 1908.

The principal results obtained in the course of the experiments detailed above may briefly be stated as follows:—

(1) The method of turpentine distillation as carried out at present at Bhowali and Kalsi is in no way defective in itself and if carried out carefully can yield commercial turpentine oil as good as steam distilled oil.

(2) It has been shown that the Indian turpentine as distilled at present at Bhowali and Kalsi contains a greater amount of high boiling terpenes than the American and French oils. The crude oil has about 35 per cent. of these high boiling constituents. This fact accounts for the low drying quality of the Indian turpentine as compared with the best imported oils.

(3) The low drying quality of the Indian oil as distilled at present may also possibly be due to the presence of the decomposition products of colophony which may have been introduced into the oil towards the later stages of the distillation. It is possible that the high temperature which obtains in the still at certain stages permits the entry of traces of colophony itself into the distillate.

(4) The above-mentioned defect of the Indian oil is easily remediable, otherwise the present method of water distillation would have of necessity to be given up for steam distillation and subsequent rectification. It has been found that simple redistillation of the present oil effects a great improvement in its quality. The best oil is produced if 20 per cent. of the total crude oil on redistillation is eliminated. But from a commercial standpoint Mr. Clutterbuck thought it unnecessary to redistil the whole of the oil. According to his plan

the distillate of 57 lbs. (the yield of oil from 300 lbs. of oleo-resin) should be divided into four fractions, the first three being of about 15 lbs. each and the last of 21 lbs. and only the fourth fraction should be redistilled in a separate copper still, stopping the redistillation when 75 per cent. of this charge has been recovered.

To put the last fraction back into the still used for the distillation of oleo-resin, though no doubt more convenient, is not recommended. This plan is worthy of trial on a commercial scale.

To improve further the quality of the oil the whole of the crude oil may be redistilled once or twice if the demand warrants this. Evidently repeated distillation will be unnecessary if the oil so produced does not command a much better price.

There can be no reason, however, why the redistilled Bhowali oil made "extra fine" by rejecting a total of 20 per cent. of crude oil should not command a much better price than the present oil, and it is, therefore, recommended that steps should be taken to manufacture the "extra fine" quality and secure a proper market for it.

(5) Rapid distillation should be avoided and care should be taken that the temperature inside the still be not so high as to cause the emission of yellowish fumes, which can be noticed by opening the charge hole from time to time, otherwise the distillate will be very acidic and sticky owing to the presence of the resin and its decomposition products, rosin oil, etc., which are carried over into the distillate. In such cases whenever yellow colouration is observed in the fumes issuing from the still, the whole distillate resulting from the charge must be redistilled before it is mixed up with the preceding distillate.

An additional reason for avoiding too high a temperature is the fact that excessive heat has an injurious effect on the apparatus, and on the quality of the oil and rosin.

The free acids formed corrode the copper of the apparatus and the copper salts so produced discolour the distillate, which becomes at times green and at times blue. If the distillate becomes discoloured, it must be redistilled and decolourized before it is mixed up with the rest of the stored oil.

(6) To avoid complaints being made regarding the variations in quality, it is recommended that suitable storage tanks should be established in both the departmental factories to collect the distillates from different charges and thus to make them all of a uniform quality.

It is hoped that the suggestions made above will prove of some value. It is possible that even when effect has been given to the recommendations made above, complaints may still be forthcoming from the buyers of the oil. The oil could be refined to any degree if such complaints were well grounded and the price offered by those from whom they proceed were to warrant extra rectification. The writer believes that no complaint can legitimately be made against the Bhowali redistilled oil as regards its quality for the purposes of painting and varnishing. But the painters and varnish-makers are known to judge a sample of turpentine oil by its odour, and the slight variations from the odour of the standard turpentine constitute in their judgment a sufficient cause for rejection of the sample. The story is related of a buyer of a leading American Varnish Company to whom a sample of nearly chemically pure pinene was sent for valuation and who returned it as not satisfactory. It is said that he opened the cork and instead of testing the oil he simply brought the mouth of the bottle close to his nose and passed judgment on the odour. Mr. Harper* says that this pure oil could not be duplicated at less than twice the price of ordinary American turpentine. This story is related here to show that it is difficult to convince painters and varnish-makers of the merits of really good turpentine oil.

In connection with the drying capacity of the turpentine oil, it may be noted here that old oil without doubt causes varnishes to dry more quickly than freshly distilled oil. This is so because

* W. B. Harper, MS.—the Utilization of Wood Waste by Distillation, page 117.

old oil, as noted previously, contains oxygen, which it has absorbed from the air and which it holds in a very loose combination; it is this oxygen which helps the varnishes to dry quickly. The old oil is further known to give better body and greater brilliancy to the varnishes, but it must be remembered that the increase in its quality of drying and imparting brilliancy is more than counterbalanced by the decrease in hardness and durability (*vide* Spon's Encyclopædia, Vol. II, page 2226).

It is evident that the imported oils are always older than the Indian oil, which as soon as it is distilled is sold to the consumer, and this fact must be taken into account when passing judgment on the drying quality of the Indian oil as compared with that of the imported oils. There is no doubt that the turpentine which has been so far produced has rightly given cause for complaints as regards its drying quality, but as regards the Bhowali redistilled turpentine oil, consumers and buyers are strongly recommended to judge it on its own merits and test its drying capacity by making experiment before they condemn it.

Opportunity may be taken here of strongly recommending to the Forest Department that Indian turpentine oil of extra fine quality should be manufactured by the departmental factories at Bhowali and Kalsi, the operation of redistillation being conducted in separate stills. This will entail no additional labour, for the men in charge of the distillation at present can very well control the process of redistillation. This step would go a great way towards giving an impetus to this important industry and the Indian oil would gain a reputation for itself.

APPENDIX B.

A Report on the Quality of the Turpentine Oil as required by Railways.

(Written for the Forest Research Institute by Puran Singh, Forest Chemist.)

Mr. Smythies, Divisional Forest Officer, Naini Tal, has been corresponding for some time past with the Chief Store-keeper,

North-Western Railway, on the direct supply of turpentine oil produced at Bhowali to the Indian Railways. In his letter No. C. 242, dated 29th November 1909, to the Conservator of Forests, Western Circle, Mr. Smythies says that 5,000 gallons of turpentine oil were sent to the North-Western Railway in the beginning of the year 1909 for trial. The Chief Store-keeper then reported that the oil supplied was not of a suitable quality as it left a greasy residue which would not readily evaporate. As already pointed out by me this defect is due to the presence of the high boiling constituents in the oil and the more complete the elimination of these constituents, the better is the quality of the oil. Mr. Smythies somewhat improved the quality of the oil, by rejecting in the process of partial redistillation the portions of oil having a higher specific gravity than 0·867. He thus got an oil which met with the acceptance of Messrs Turner, Morrison & Co., of Calcutta, who purchased wholesale the total output of the year 1910. It was this sample that Mr. Smythies sent again to the Chief Store-keeper, North-Western Railway, for trial in January 1910. This sample also was rejected by the Chief Store-keeper on the same grounds.

On a reference from Mr. Smythies, I took up the question again and eliminated from the oil the fractions which left a greasy residue. This sample prepared by me in the Laboratory by redistilling the crude oil to the extent of 80 per cent. was sent by Mr. Smythies to the Chief Store-keeper, North-Western Railway, and it was reported upon by him as follows:—

> "The sample sent by you is suitable for our work. I have made arrangements to procure our requirements of turpentine for this year from England, but if you will intimate your outturn and state your prices I may be able to enter into an agreement with you for supply during 1911, provided, of course, that you guarantee uniform quality according to sample now reported on."

The sample thus approved of was a highly refined oil which almost all distilled below 167° C. To avoid the heavy loss of 20 per cent. of oil in the preparation of this special grade a new process of distillation at a much lower temperature was adopted

(*vide infra,* this Note, page 21). An oil distilling about 90—94 per cent. below 167° C. was prepared on a fairly large scale by the new process at Bhowali. On evaporation, when exposed in a thin layer on a glass plate, it left a clean dry surface. A quantity of this oil was again sent to the Chief Store-keeper, North-Western Railway, for trial. He reported on its quality as follows:—

> "The sample referred to is only suitable for outside work and is not as good as the sample sent previously and which was reported on favourably . . . . . I regret to state that I cannot accept any turpentine according to last sample sent, as the whole of my supplies must be of uniform quality. I cannot keep aside particular qualities for particular kinds of work."

According to my tests, however, the two oils mentioned above, one reported as suitable and the other unsuitable, were practically equal in quality. The first oil, which was reported on favourably, distilled over about 95 per cent. below 167° C., while the second oil, which was reported on unfavourably, distilled over about 90—94 per cent. below 167° C. As for drying tests, even the residue of the latter above 167° C. left no greasy residue on evaporation, hence it must be taken in its practical application to be equal to the first oil.

The opinion of the Chief Store-keeper on the two oils, therefore, seemed contradictory. In order to acquaint myself with the actual requirements of the Railway Workshops, I secured an introduction to Mr. Keatinge, the Chief Store-keeper, North-Western Railway, from Rai Sahib Bishan Dass, Personal Assistant to the Manager, North-Western Railway.

Mr. Keatinge was kind enough to make the following suggestion to settle the point:—"I have been endeavouring for the past two years or more to introduce turpentine of country manufacture on the Railway, but have always met with the objection that it is defective in quality and unsuitable and, therefore, I have been compelled to obtain my requirements from England. I am afraid any further attempts carried on with correspondence will not result in any good. A few practical demonstrations witnessed by the

Forest Chemist will give him a very much better idea of what we really want than six months' letter writing." This suggestion was acted upon.

Accordingly I went to Lahore taking with me the following four samples:—

A. Spirit distilled crude turpentine oil not as good as the first sample of the same sent to North-Western Railway shops for trial. On fractional distillation it had about 85 per cent. passing below 165° C., while the first sample sent had about 94 per cent. passing below the same temperature.

A^1. The sample A redistilled. Though redistilled, this was only equal to the sample of crude spirit distilled oil, previously sent to North-Western Railway shops; on fractional distillation it gave 95 per cent. passing below 167° C.

A + B + C + D. Crude turpentine oil of Bhowali redistilled, rejecting 10 per cent. of the total output. About 78 per cent. distilling below 167° C. This oil was being accepted by Messrs. Turner, Morrison & Co., of Calcutta, while it was wholly rejected by the North-Western Railway.

$A^1 + B^1 + C^1 + D^1$. Redistilled oil, rejecting 20 per cent. of the total output of the crude oil. About 90 per cent. distilling over below 167° C. Not refined or redistilled to the same extent as the sample prepared in the Laboratory and sent to the Chief Store-keeper, and which had been approved by him.

As the result of a personal interview with the Chief Store-keeper, North-Western Railway, I found out that there was no critical examination of the oil on purchase. Its value was adjudged on the report of the Superintendent, Carriage and Wagon Workshops. The Chief Store-keeper kindly gave me an introduction to the Deputy Superintendent, Carriage and Wagon Workshops, who sent me on to the Workshop Manager. The Foreman in charge of the Paint Shops was called in by the Manager, but

being only temporarily there he could give no information whatever as to the quality of the turpentine oil required by the Railways. I had to wait two or three days till the return of the permanent Foreman from leave, to whom the Workshop Manager sent me. I requested him to test the four qualities of the oil I had with me in my presence, comparing each one of them with the American oil that he had. He had two qualities of the American oil, one he called "very superior" and the other "common." He then tested the six samples of the oil with the following results:—

Common American oil (used for rough work).	Sticky surface.
Very superior American oil .	Very slightly sticky, almost dry surface.
A	Slightly sticky surface.
A^1	Perfectly dry surface.
$A+B+C+D$ . . .	Sticky surface.
$A^1+B^1+C^1+D^1$ . . .	Perfectly dry surface.

A^1 was slightly better than $A^1+B^1+C^1+D^1$, A was better than $A+B+C+D$ and $A^1+B^1+C^1+D^1$ was equal to the "very superior" American and A^1 was slightly better than "very superior" American oil, according to the Foreman's test. Both A and $A+B+C+D$ were better than the "common" American oil. This was our unanimous conclusion. These results happily were exactly in accord with my own opinion about the samples based on the results of fractional distillation. The Foreman agreed with me that the test applied by him was rough and that it was possible that it might be somewhat misleading. For example, the superior American oil gave a very slightly sticky surface, not because it was inferior oil, but because it was rather old. The same oil if kept still longer would by his test be liable to rejection. I could not find out from the Foreman the cause of the rejection of the spirit distilled sample that was previously sent to the shops from Bhowali for trial, as the test of that sample was done when he was on leave. The following is the copy of the Foreman's report to the Workshop Manager who let me have a copy:—

"I have tested four samples of turpentine brought down by the Forest Chemist marked (1) A, (2) A^1, (3) $A+B+C+D$ and (4) $A^1+B^1+C^1+D^1$. I find (2) and (4)

very good and suitable for any work of ours and equal to home supply. The others (1) and (3) are not so good and are only suitable for our rough work. (1) is slightly better than (3)."

I drew the attention of the Foreman to the fact that according to his test the oils (2) and (4) should be considered better than the home supply and A should be pronounced equal to the "very superior" American oil. The sample (3) only could be called second class equal to the "common" American turpentine fit for their rough work. On this, he humorously remarked that what he had written was a good enough certificate. It should, therefore, be taken as settled that an oil with 90—95 per cent. passing below 167° C. when fractionated in an ordinary fractional distillation flask at a barometric pressure of $27\frac{1}{2}''$ is quite suitable for any work of the Railway Workshops. Though I was given no opportunity to try the actual paint experiments in the shops, nor was it considered necessary, yet I am of opinion that for their practical purposes an oil even slightly inferior would also answer.

As pointed out elsewhere in the body of this Note, it is easy to produce this quality of the oil in the very first distillation by methylated spirits, by regulating the rate of distillation, by skilfully "cutting" the still and finally by thoroughly washing the crude oil thus obtained with lime water.

In conclusion I wish to express my gratitude for the kind assistance given to me by Rai Sahib Bishan Dass and Mr. Keatinge.

APPENDIX C.

The Quality of the Turpentine Oil as required by the Indian Ordnance Department.

The following specification to govern supply and tests of spirits of turpentine to the Indian Ordnance Department is given in their published specification No. 72, dated 9th August 1904:—

"The liquid should be transparent, clear and colourless, or should have almost pale-yellowish colour. It should possess the well-

known and characteristic odour of the material. When ignited in an open dish, a small sample should burn with a bright and smoky flame. Its specific gravity at 100° F. should lie between 0·845 and 0·865. Practically the whole of an one-ounce sample should distil between the temperatures of 310° and 320° F. (between 155° and 160° C.), no appreciable quantity passing over until the thermometer has reached the lower of these two limits, and the thermometer remaining then almost stationary until nearly the whole has distilled."

According to this specification it is apparent that the Ordnance Department requires highly rectified oil. The Forest Department can supply the oil, which compared with the oil of above specification stands as below. The sources of the American and French oils being quite different from that of the Indian oil, the slight variations are but natural.

——	The Indian oil which can be supplied without extra refining, *i.e.*, by distilling slowly the crude resin with 70 per cent. alcohol below 100° C.	The oil used at present by the Ordnance Department.
Colour . . .	Colourless to very pale-yellow. (The latter in the case of old oil.)	Very pale-yellow.
Specific gravity .	0·864—0·867	0·867
Saponifiable matter .	*Nil*	*Nil*
Distilling below 170° C.	95 per cent.	Distilling below 160° C. 95 per cent.

The Indian oil can still further be refined by repeated distillation to yield an oil which would wholly distil over below 160° C., but the cost would be prohibitively high.

The Ordnance Department cannot, however, pay more than Rs. 1-8-0 and Rs. 1-10-0 per gallon for the Indian oil and, therefore, the question of supplying them must be dropped as long as Rs. 2-0-0 to Rs. 2-4-0 is obtained in the open market.

APPENDIX D.

I.

The Reports on *Pinus longifolia* Oil from the Imperial Institute, London.

Extract from the Interim Report of Professor Dunstan on the Composition of Turpentine Oil from Pinus longifolia Resin.

The following is an extract from the interim report on Indian turpentine by Professor W. R. Dunstan, M.A., F.R.S., Director, Imperial Institute, London, dated 27th July 1909:—

"The investigation of the constituents of the turpentine oil of *Pinus longifolia* was conducted on a sample from the Jaunsar Division, United Provinces, as this was found by preliminary examination to have undergone the least oxidation of the specimens forwarded from India.

"The oil was colourless except for a very faint buff tinge. Portions of it, after having been dried by contact with dry sodium sulphate, had a specific gravity at 15° C. of 0·869 as compared with water at the same temperature, and a specific rotatory power (α) D $= -3° 2'$.

"A portion was distilled to remove the comparatively non-volatile matter, and the distillate was submitted to a long series of fractional distillations to separate the volatile constituents from one another. These distillations were made under diminished pressure, approaching a vacuum, so that the boiling was effected at temperatures not exceeding 100° C. in order that the constituents might not be altered by the heat applied.

"The non-volatile matter amounted to about 6 per cent., but as the amount of non-volatile matter in turpentine oil slowly increases owing to atmospheric oxidation, it may have been less when the oil was first prepared.

"The volatile constituents were separated into two portions, differing considerably in their boiling points. The portion with the lower boiling point amounted to

one-third of the total volatile oil, and was found to be lævo-pinene. Purified portions had a boiling point of 157·5° C., a specific gravity at 15° C. of 0·862 compared with water at the same temperature, and a specific rotatory power (α) D = – 42°.

"The remaining two-thirds was much less volatile and appeared to be mainly composed of a turpentine oil having a boiling point of 173° C., a specific gravity at 15° C. of 0·867 as compared with water at the same temperature, and a specific rotatory power (α) D = + 14° 6′.

"It was found to contain a considerable quantity of the terpene sylvestrene, but the specific gravity of sylvestrene at 15° C. is 0·852, so that still another constituent of higher specific gravity must be present. This third constituent proves to be very difficult to separate from the sylvestrene, but efforts are being continued to isolate it and determine its nature.

"Lævo-pinene is the principal constituent of French turpentine oil, which is obtained from *Pinus Pinaster*, Solander.

"Sylvestrene is found in commerce as one of the components of Pine Tar Oil (also known as "Russian Turpentine Oil"), which is obtained as a first product of the dry distillation of the resiniferous roots of the common pine (*Pinus sylvestris*). This oil is made in Eastern Germany, Poland, Finland, Northern Russia and Sweden. It is of inferior quality to turpentine oil; this, however, is due to constituent produced by the dry distillation which gives it an empyreumatic odour."[2]

II.

The Report of Professor Dunstan on Turpentine Oil from India, No. 35375, dated 18th January 1911.

(*The samples sent being the spirit distilled oil, prepared at Bhowali.*)

The samples of turpentine oil, which are the subject of this report, were forwarded to the Imperial Institute by the Assistant Conservator of Forests, Naini Tal, United Provinces, with letter

No. 650—15-9, dated 8th August 1910. The oil was stated to have been prepared at the Government Turpentine Distillery at Naini Tal from the resin of the "Chir pine" (*Pinus longifolia*), and it was desired to ascertain its value as compared with the turpentine oil of commerce.

Description of samples.

The samples were two in number, marked "A"* and "B,"* each sample weighed 16 lbs. and consisted of colourless turpentine oil.

Results of examination.

The specific gravity and rotatory power of the oils were as follows:—

	A	B
Specific gravity at 15° C. . .	0·871	0·868
Optical rotation in 100 mm. tube .	—0° 45'	—2° 10'

The samples were subjected to fractional distillation with the following results:—

——	A		B	
	Percentage of total sample by volume.	Optical rotation in 100 mm. tube.	Percentage of total sample by volume.	Optical rotation in 100 mm. tube.
Fraction boiling at—				
165° C. or below .	1	—9° 45′	1	..
165° C. to 170° C. .	54	—5° 15′	55	—7° 15′
170° C. to 175° C. .	25	+2° 0′	28	+0° 20′
175° C. to 195° C. .	12	+6° 35′	9	+7° 5′
Residue . . .	7	+10° 45′	6	+17° 25′

* A and B are spirit-distilled samples of turpentine oil, A being a slowly distilled one and B being a rapidly distilled one. For the results of fractional distillation of A and B obtained at Bhowali and Dehra, see pp. 26, 27 and 28 of this Note, and for those of A obtained at Pusa, see p. 30.

The above figures show that the present samples yielding practically no distillates below 165° C. are quite different from American turpentine oil, which should yield not less than 70 per cent. by volume between 155° and 160° C. They are of the same nature as a sample of turpentine oil from *Pinus longifolia* from the Jaunsar Division, United Provinces, previously examined at the Imperial Institute (see Imperial Institute Report, dated 27th July 1909). One-third of the latter was lævo-pinene, boiling at 157° C. and having a rotatory power in a 100 mm. tube of $-36\frac{1}{2}°$, and two-thirds consisted of a mixture of sylvestrene and other high boiling terpenes with a boiling point of 173° C. and a rotatory power in a 100 mm. tube of $+13°$.

III.

Extract from the Report of Professor Dunstan on Turpentine Oil from India, No. 40471, dated 23rd February 1912.

(The samples being of the acetic acid-distilled oil, prepared at the Forest Research Institute Laboratory, Dehra Dun.)

Description of samples.

The samples consisted of colourless turpentine oil and were labelled as follows:—

(1) "Crude turpentine oil distilled through acetic acid from *Pinus longifolia;* made by the Forest Chemist, Dehra Dun." Weight 13 oz.

(2) "Rectified turpentine oil from *Pinus longifolia* distilled through acetic acid; made by the Forest Chemist, Dehra Dun." Weight 1 lb.

In the present report the crude and refined oils are designated C and D respectively.

Results of examination.

The samples were examined with the following results, compared with the corresponding figures for two samples marked A and

B previously examined at the Imperial Institute (see Imperial Institute Report, dated 18th January 1911):—

—	Present samples.		Previous samples.	
	C* (crude).	D* (refined).	A	B
Specific gravity at 15° C..	0·868	0·866	0·871	0·868
Optical rotation in 100 mm. tube.	+0° 20′	0° 40′	0° 45′	—2° 10′

On fractional distillation the two oils gave the following percentages by volume, compared with those yielded by the previous samples A and B and by a sample of rectified turpentine oil purchased in London:—

—	Present samples.		Previous samples.		Rectified oil purchased in London.
	C (crude).	D (refined).	A	B	
Fraction boiling at—					
165° C. or below	..	..	1	1	85
165° C. to 170° C.	43	56	54	55	6
170° C. to 175° C.	40	33	25	28	
175° C. to 180° C.	8	4½			
180° C. to 190° C.	3	1½	12	9	9
190° C. to 195° C.	..	..			
Residue . . .	6	4	7	6	

* Samples of C and D were also fractionated at Dehra before they were sent to London with the following results :—

	C	D
Below 160° C.	10%	16%
Between 160°—167° C.	75%	78%
Residue above 167° C.	15%	6%

(The oil distilled very constantly between 160°—165° C.)

These results are somewhat different from those obtained for A and B as recorded on pp. 26, 27 and 28 of this Note, and the difference is probably due to the difference in the age of crude resin that was, in this case, distilled in the Laboratory.

The optical rotation in a 100 mm. tube of the various fractions of samples A, B, C and D are given in the following table:—

—	PRESENT SAMPLES.		PREVIOUS SAMPLES.	
	C (crude).	D (refined).	A	B
165° C. or below . .	..	..	−9° 45′	..
165° C. to 170° C. . .	−5° 25′	−4° 40′	−5° 15′	7° 15′
170° C. to 175° C. . .	+2° 0′	3° 0′	+2° 0′	+0° 20′
175° C. to 180° C. . .	+8° 5′	..		
180° C. to 190° C. . .	..	..	+6° 35′	+7° 5′
190° C. to 195° C. . .	..	..		
Residue . . .	..	..	+10° 45′	+17° 25′

From the above results it appears that the rectified oil D is considerably richer in low-boiling terpene than the crude oil C, but that it is much inferior in this respect to the rectified turpentine oil purchased in London, since 85 per cent. of the latter distilled below 165° C. whilst none of the Indian oil did so. The rectified oil D is, however, superior to A and B, as 89 per cent. of it distilled below 175° C. against only 80 and 84 per cent. respectively in the case of the latter samples. The crude oil C is intermediate between samples A and B, since 83 per cent. of it distilled below 175° C.

Experiments were made to compare the behaviour of sample D on exposure to air with that of the turpentine oil purchased in London, and it was found that the Indian oil evaporated more slowly, oxidised much more rapidly and gave far more oxidised residue than the London oil. In these experiments, quantities of 10 c.c. of each oil were exposed in glass dishes 8 cm. wide, with vertical sides 3·6 cm. high. In six days the London oil had evaporated, leaving an immobile film of thick liquid, whilst the Indian oil left a layer of syrupy liquid, which became immobile two or three days later. After seven weeks the residue left by the

Indian oil was still sticky where the layer was thick and "tacky" where it was thin, whereas the London sample had dried to a thin "tacky" layer. The Indian oil finally left $1\frac{1}{4}$ grams of residue whilst the London oil left only $\frac{1}{4}$ gram.

The varnish-making properties of the two oils were also compared by using them to prepare solutions of zinc resinate. On leaving the oils for 17 days in contact with an excess of the resinate, the London oil proved to be the more powerful solvent of the two, giving a very thick syrupy liquid which had to be diluted with more oil before it could be used; whilst in the case of the Indian oil only a thin syrupy solution was obtained. This thin solution, however, when painted on sized wood gave a very satisfactory varnished surface, so that it appears that the Indian oil can be used quite well for varnish-making.

Remarks.

The previous examination of Indian turpentine oil at the Imperial Institute showed that only one-third of the oil of *Pinus longifolia* is pinene, boiling at 157·5° C., and that the remaining two-thirds is mainly composed of terpenes boiling at a considerably higher temperature, *viz.*, 173° C. (see Imperial Institute Report, dated 27th July 1909). These facts and the results of the present investigation show that there is no possibility of this turpentine oil being accepted in commerce as similar to American and French turpentine oils, which are pinene oils.

In the Laboratory it is possible by repeated distillations to separate the pinene from the other terpenes, but it is very unlikely that this could be done profitably on a large scale. It, therefore, seems inevitable that the oil must be sold on its own merits as Indian turpentine oil, when it may be expected to realise a price equal to or somewhat better than that of Russian turpentine oil.

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The analytical results quoted by the Forest Chemist in the letter forwarding the present samples C and D show a marked improvement in the oil distilled with methylated spirit or acetic acid, compared with the oil as ordinarily obtained. Trials at the distillery

should, therefore, be made to decide whether the improvement in the oil repays the extra cost of using methylated spirit. The use of acetic acid seems inadvisable as it would in all probability have a destructive action on the stills and other vessels.

It should be borne in mind in comparing the results of distillation experiments made in India with those of the tests made in London that any variation in atmospheric pressure due to differences of elevation will materially affect the boiling point of liquids.

APPENDIX E.

Turpentine Substitutes.

For some time past, attempts have been made in Europe to prepare mineral substitutes for turpentine oil. They are either a mixture of hydrocarbons derived from coal tar distillation or of light mineral oils derived from the fractional distillation of petroleum. The "mineral base" for preparing the petroleum substitute is obtainable at about 15 cents per gallon. It has a specific gravity of about 0·810 and is quite free from any objectionable odour. It resembles in its appearance benzin, but has a flash point identical with that of turpentine, *viz.*, 105° F. This "mineral base" is obtained by "cracking" the heavier petroleum oils and carefully fractionating the distillate. The substitutes for turpentine prepared with this "mineral base" are being freely placed on the market. As a solvent, or as a diluent, they answer the various industrial purposes very well. Their cheapness recommends them for use in varnish and paint industries.

The different blends of these different turpentine substitutes need not be mentioned here. The subject has been referred to, to show that the paint and varnish industries, finding a cheap substitute in the mineral turpentine, are not tied down to turpentine oil which is becoming dearer and dearer every day.

Last time when the writer of this Note was at Lahore Railway Workshops, he gathered from the officers concerned that after a fair trial of these "hydrocarbon substitutes" of turpentine, they were satisfied that their use will be cheaper and in every way better than that of turpentine oil. This has, however, yet to be proved.

APPENDIX F.

Imports of Turpentine Oil into India and the Future Outlook.

According to the statistics compiled by the Director-General of Commercial Intelligence and communicated by him in his letter No. 4748, dated the 28th July 1911, to the Inspector-General of Forests, the total quantity of turpentine oil imported into India during 1910-11 was 181,979 gallons worth Rs. 4,06,593 detailed according to several provinces as follows:—

——	Gallons.	Value in rupees.
Bengal	73,688	1,87,055
Madras	16,615	42,057
Bombay	63,245	1,22,800
Burma	12,948	35,048
Sind	15,271·6	19,189
Eastern Bengal and Assam	211·5	444

According to the available statistics of the Bhowali Government Distillery, the annual output of turpentine oil has been steadily increasing as the following figures for six years from 1905 to 1910 will show:—

Year.	Annual output in gallons.
1905	6,130
1906	10,960
1907	14,200
1908	14,580
1909	22,200
1910	29,900

Evidently there is a great room for the expansion of this industry in India in order to meet the requirements of the Indian market, which, with the extension of railways and various industrial undertakings, seem likely to gradually increase unless a cheap and efficient substitute can be found. It is, however, improbable that the Indian oil would be able to replace some of the best grades of the American oil unless better qualities of oil from *Pinus Khasya, P. Merkusii* and *P. excelsa* are also brought in.

PART II.

Note on the Clarification of Indian Rosin.

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At the instance of the Inspector-General of Forests to the Government of India, the Conservator of Forests, Western Circle, United Provinces, Naini Tal, started an enquiry as to the commercial value of the Indian rosin manufactured at the Bhowali Turpentine Distillery for mixing with shellac for which purpose a large quantity of American rosin is imported and sold at higher prices than what the Indian rosin has fetched. According to the reports obtained by the Conservator, the Indian rosin being of too dark a colour, was found to be unsuitable as a mixing agent. With a view to find out a cheap commercial method for the proper clarification and if possible the decolourisation of Indian rosin, experiments have been carried on for some time past by the writer and this Note embodies the main results obtained. It is hoped that the suggestions embodied in this report if properly carried out will improve the quality of the Indian rosin to the required standard of colour and purity.

Before giving the results of the author's experiments, a general description of rosin and of the French and American methods of its manufacture may well be given here.

General properties of rosin.

Rosin as it is well known is the fixed residue obtained as a by-product in the distillation of turpentine. It is a transparent or translucent resin of a faint terebinthinous odour. It is generally tasteless. It is extremely brittle and has a shallow concoidal fracture. It varies in colour from a pale amber to dark reddish brown. The darkest kind has the commercial name of "Black Rosin" and the light coloured variety is known as "White Rosin." It softens at 70°—80° C. and in boiling water assumes the consistency of a semi-fluid. It generally completely melts at 130° C. though sometimes at a slightly higher temperature. When very strongly heated, it ignites and burns with a very smoky yellow flame, leaving behind traces of mineral matter. The specific gravity of

rosin ranges between 1·07 to 1·08 and at times it is as high as 1·04 to 1·1. It is quite insoluble in water. It slowly dissolves in equal weights of alcohol or glacial acetic acid and readily so in methyl and amyl alcohols, acetone, ether, chloroform, carbon bisulphide, alkalies and fixed and volatile oils. It dissolves also in benzene and petroleum ether. The alcoholic solution of rosin shows acid reaction. The acid number of American rosin varies from 146·01 to 157·24 and saponification number from 157·24 to 198·24. Its iodine number varies from 120 to 185 when treated with Hubl solution for 18 hours.

Its chemical composition has been the subject of various researches with very conflicting results. Generally speaking, rosin may be said to consist of about 90 per cent. Abietic acid ($C_{20}H_{32}O_2$) and 4 per cent. Abietic anhydride ($C_{40}H_{58}O_3$) and 6 per cent. hydrocarbons or unsaponifiable matter. The composition and constants of colophony vary with its origin, nature and mode of preparation.

Colophony is extensively used in the manufacture of soaps, varnish and resinates. It is also used to some extent in pharmacy and veterinary practice. As an adulterant, it is in demand for adulterating shellac, dammar and dragon's blood. According to Fahrion, colophony, as required by the varnish-maker, should be light in colour, high in acid number and as low as possible in its ester number, unsaponifiable matter and substances insoluble in petroleum spirit.

The shellac manufacturers in India have laid down no such constants for rosin required by them, but as far as the writer has been able to find out it is pale amber grades of rosin that they require for light-coloured shellac and reddish-yellow for other varieties.

A summary of French and American methods of rosin manufacture.

The colour of rosin depends on the manner in which the turpentine distillation is conducted and on the temperatures employed therein. It also varies according to the origin and kind of crude resin used, the season of tapping and the degree of care taken in the manufacturing processes. In France and America great care is taken in classifying the crude resin into different grades, according to the season of the year in which the trees are tapped and the successive number of annual tappings. It may be

remarked here that the consistency and colour of the crude oleo-resin varies with the season of the year and the temperature at the time of its exudation. The spring and summer collections give rosin of higher and light coloured grades and again the collections from the "Virgin Dips" (*i.e.*, from trees tapped for the first time) yield the so-called "Window Glass" and "Water White" grades of rosin and those from "Yellow Dip" (*i.e.*, resin obtained from trees tapped in successive years) give dark-coloured varieties.

The American works classify rosin into the following grades according to colour, varying from almost colourless to the darkest opaque:—

W. W.	Water white.	Best.
W. G.	Window glass.	
N.	Extra pale.	High grades.
M.	Pale.	
K.	Low pale.	
J.	Good No. 1.	
H.	No. 1.	
G.	Low No. 1.	Ordinary colohpony.
F.	Good No. 2.	
E.	No. 2.	
D.	Good strained.	
C.	Strained.	
B.	Common strained.	Low grades.
A.	Black.	

Besides the great care that is taken in the collection and classification of crude resin, the colour and quality of rosin is influenced by the method of distillation depending chiefly on the temperature employed. The crude resin is melted either over an open fire or by a means of closed steam coils, and filtered before distillation. After distilling off the turpentine oil the molten colophony is drawn off from the still; it is then moulded, and barrelled. Before finally moulding it, it is customary to heat it over an open fire for some time to drive off the last traces of oil from it. This operation reduces its stickiness. Sometimes darker varieties of rosin are boiled by soap-makers with salt water to reduce their colour. In the factory, the finer grades are exposed to sunlight to make the "Water White" and "Window Glass" varieties of rosin. Rosin obtained from the spring resin or "Virgin Dip" is ladled into shallow

saucers and is exposed to sunlight from 10 to 30 days according to the weather. Exposed to the bright sunlight of moderate heat, the amber coloured rosin, for example, becomes gradually clearer in colour, finally becoming almost colourless and transparent.

Effect of different methods of distillation on rosin.

Rosin is generally overburnt in the still if turpentine distillation is completely carried out. After a calculated amount of oil has distilled over, it is best to "cut" the still. For finer grades of rosin it is essential to leave some amount of the oil in it, which can be driven off by heating it over an open fire. Usually the still is "cut" at a point when the distillate approximates to one part of turpentine and 9—10 parts of water. At this stage only a negligible quantity of oil is left in the still. Any attempt to distil this last portion of the oil darkens the colophony. In America, when "Virgin Dip" is under distillation, the still is "cut" even earlier.

A great deal, as said above, depends on the process of distillation, which if carried on at a low temperature gives better qualities of both the oil and the rosin. For example, rosin obtained in turpentine distillation by furnace heat only is of inferior quality and often dark coloured and smoky. (J. L. Pigot, Report on the manufacture of spirits of turpentine and colophony, 1897.) It is due to the fact that in this process the crude resin has to be heated to 158° C. and more. The rosin obtained from turpentine distillation, where both the furnace heat and the superheated steam are employed is of better quality than that obtained in the process mentioned above or in steam distillation of turpentine where the temperature is kept at about 150° C. by letting in steam at a pressure of 4·7 kilograms per square centimetre, both into the steam jacket containing crude resin and into the steam coil inside the jacket. (See J. L. Pigot, *loc. cit.*)

Water distillation, however, is the only process that has been adopted up to very lately in India.* This process lies between the furnace heat process and steam distillation. (For the description of the latter two processes, see J. L. Pigot, *loc. cit.*, and of the former process, see Chapter I, Part I of this Note.) At Bhowali, where

* It is understood that steam distillation has very recently been tried near Lahore, but the results are not yet available.

turpentine distillation is carried on, it was seen that the colour of colophony varies according to the temperature prevailing in the still, becoming darker if distillation is carried on rapidly and consequently at high temperatures, and of lighter colour when otherwise.

Some time ago a comparative examination was made of Indian rosins obtained by the water distillation process at two different factories at Kalsi and at Bhowali and of a specimen of rosin prepared by the writer by distilling the crude resin from Bhowali with steam in his Laboratory, the results of which are tabulated below. It may be remarked, however, that as regards the colour of these samples the observations made in the table cannot be strictly accurate, because the quantity obtained in the Laboratory was somewhat small for satisfactory comparison.

——	Colour.	Ash.	Loss at 120° C.	Loss at 172° C.	Acid. number.	Saponification No.	Sp. gr.
Colophony from steam distillation of Bhowali resin.	Light amber.	*Nil*	0·749%	0·321%	177·07	197·12	1·07 to 1·08
Colophony from Bhowali.	Darkish yellow.	*Nil*	0·406%	0·650%	175·27	195·60	Do.
Colophony from Kalsi	Do.	*Nil*	0·421%	0·515%	174·48	194·38	Do.

Colophony as obtained from steam distillation appears to contain a greater amount of moisture and a smaller amount of other volatile matter than that obtained from Kalsi or Bhowali. This difference may be due in part to the small scale on which the Laboratory experiment was carried out. On the whole there seems to be very little difference between the quality of these rosins.

Apart from steam and water distillation, the writer has devised a new process for the distillation of turpentine oil in India which does not necessarily involve the change of plant in use at present and is pre-eminently suitable for the distillation of *Pinus longifolia* resin. In this process use is made of methylated spirits to reduce the temperature of the still as well as the distillation temperature of the oil. It was seen that most of the oil could be distilled without having to raise the temperature of the still above 100° C. (For a detailed description of the process, see Part I of this Note.) The quality of rosin obtained by this method is superior in point of

colour and transparency to that obtained by either water distillation or steam distillation.

Both for the quality of the oil and the rosin, it may appropriately be pointed out here that whatever process be adopted, it is essential that the still must be "cut" and the distillation be not allowed to proceed to its utmost limit.

Experiments on the Reduction of Colour of Indian Rosin.

Besides the trials made at Bhowali to improve the colour of rosin by adopting spirit distillation or by carrying on water distillation at a low temperature, the writer made a series of comparative experiments in the Laboratory to reduce the colour of the Indian rosin with results given below. The observations as to the colour were made on slabs of equal size prepared from the same quality of rosin by different treatments. The rosin treated was of dark deep-yellow and light-yellow colours.

Action of simple heating.—First of all it was seen that repeated melting has an injurious effect on the colour of rosin. Pale yellow American rosin when melted only once changed into reddish yellow, and the colour deepened still further on repeated meltings. This may be attributed to either slight charring or aërial oxidation under the influence of a high temperature.

Action of steaming.—Steaming has no good effect on the colour of rosin. It darkens it and makes it opaque due to the presence of water.

Action of sulphur dioxide and chlorine.—Both of these bleaching agents have destructive effect on rosin as they darken it to some extent.

Action of copper, lead and iron in metallic form.—When a pale coloured variety of rosin is heated strongly to perfect fusion with metallic copper, lead or iron, its shade becomes darker. After repeated observations it was found that the contact of these metals with strongly heated rosin injuriously affects its colouration. The stills in the turpentine factories are generally made of copper and hence some amount of discolouration unavoidably takes place in the stills.

Action of metallic tin.—Of all the common metals it has come under the observation of the writer that contact of molten resins with metallic tin exerts a beneficial influence on the colour of different resins. It was seen that by keeping melted rosin in contact with granulated tin there was a distinct improvement in its colour, particularly the dark coloured variety was reduced to half of its original depth of colour.

Action of albumen.—Albumen in the shape of animal blood clarifies rosin owing to coagulation consequent on the heat of the melted rosin and by absorbing in itself the suspended impurities. It improves the colour of rosin appreciably and makes it perfectly transparent, but the process is too costly to be employed on a commercial scale.

Action of salt.—Boiling rosin with salt solution as done by soapmakers to reduce its colour is a long and tedious operation and not entirely effective.

Action of acetic acid.—The addition of a small quantity of acetic acid to the molten rosin makes the latter transparent and bright. But the addition of a free acid cannot be recommended, as its presence is objectionable.

Action of potassium chlorate and nitre.—Oxidising agents like potassium chlorate and nitre in small quantities impart a reddish tinge to the pale straw varieties of colophony, but in excess, they have an injurious effect on the colour and composition of rosin. Pale rosin heated with them for a long time changes colour to a deep dark red.

Action of carbon dioxide, hydrogen and nitric oxide.—A passing reference may be made here to a recommendation made by certain authors to bleach rosin in small quantities by introducing a gentle current of carbon dioxide, hydrogen or nitric oxide gas into molten rosin for some time. The efficacy or otherwise of these agents has not been tried by the writer as their application on a commercial scale is out of the question.

Action of sunlight.—A thin layer of yellow rosin was exposed to sunlight on a glass surface for ten days with the result that it was entirely bleached water white. It is questionable whether sunlight bleaching of rosin in India will be commercially successful on account of the length of the process.

Action of crystalline alum.—The action of crystalline alum for clarifying rosin is remarkable. A small quantity of powdered crystalline alum when thrown into a hot liquid rosin pan held over an open fire, and stirred, gives rise to a brisk effervescence on account of the rapid escape of the water of crystallisation from alum. Alum losing its water of crystallisation rises to the surface in a spongy mass collecting in itself the suspended impurities of the rosin and removing its green colouration due to the traces of copper salt from the stills. The floating alum sponge is skimmed off, the rosin is then filtered through a fine sieve or cloth. From the alum residues pure alum can be recovered for further use.

Commercial experiments at Bhowali.—The last mentioned method of clarifying rosin with crystalline alum appeared to be very suitable for application on a commercial scale. Accordingly, experiments on a large scale were tried at Bhowali in 1910, the results of which are tabulated below. The shellac merchants, to whom the samples of pale alum clarified rosin were sent for opinion, reported that it was desirable to impart to it a reddish tint characteristic of the imported colophony. As stated above it is not difficult to impart the required reddish tint to the pale variety. In pursuance of the wishes of the shellac merchants rosin of various shades was produced at Bhowali by clarification with crystalline alum or by varying mixtures of alum and nitre as will be seen from the table below:—

Number.	Description of the treatment.	Colour as observed.	REMARKS.
A	Rosin ½ md. clarified with a mixture of 1 sr. alum crystalline and 1 sr. nitre boiled together and filtered through cloth.	Darkish red.	
B	Rosin 1½ mds. boiled with 1 sr. of mixture of equal parts of alum and nitre filtered through cloth.	Transparent, reddish pale.	
C	1½ mds. rosin added to ½ sr. nitre.	Redder than B.	
D	1½ mds. rosin added to ¼ sr. nitre.	A slight reddish tint.	

Number.	Description of the treatment.	Colour as observed.	REMARKS.
E	2 mds. colophony added to 1 sr. nitre alone.	Reddish yellow.	
F	2 mds. rosin added to $\frac{1}{2}$ sr. nitre alone.	Reddish tinge, transparent pale.	
G	2 mds. rosin clarified with $\frac{1}{4}$ seer nitre.	Light colour.	
H	2 mds. rosin clarified with 2 srs. alum plus $\frac{1}{2}$ seer nitre.	Reddish pale lemon colour.	
I	Rosin clarified by alum crystalline, 1 sr. to 1 md.	Pale.	
J	Prepared by re-melting the rosin clarified by alum alone.	Deep colour with reddish tinge.	

The process of clarification followed in the above experiments may be summed up as follows:—

It is better to take the molten rosin as it comes out of the still to a separate clarifying shed fitted up with the required number of copper cauldrons preferably tinned inside and set in a suitable furnace. The rosin has to be heated over an open fire for some time, in order to drive off the last traces of the turpentine oil, preferably with a small quantity of water. When rosin begins to seethe the clarifying mixture in fine powder has to be introduced and the whole mass stirred from time to time. When alum, losing all its water of crystallisation, comes to the surface in the form of a sponge, the fire may be drawn off from below, the alum skimmed off and the clarified rosin filtered through a fine cloth. Finally it is moulded and packed.

Commercial Results.

The samples D, E, F, G and J were sent through the Imperial Forest Economist to Messrs. Hoare, Miller & Co., Calcutta, for valuation, who reported as follows:—

> "The standards 'D' and 'J' most nearly approximate the standard G imported from America and Europe. The other grades would not be of the same value owing to their yellow and black tint.
>
> "We have tried the market with the samples and have been offered Rs. 7-8 per cwt. nett for 20 tons of rosin equal to your grade 'D,' which is near enough to compete successfully with imported 'G' and 'F.' For 'J' we might obtain annas 12 less. Both these prices would be for goods landed in Calcutta this month."

This letter is dated 18th August 1910. Since then the price of imported colophony has gone up and at present even the unclarified rosin of Bhowali is selling at about Rs. 6-12 per maund f. o. r. Kathgodam.

The sample "I" was not well reported on by this firm, but the same sample was favourably reported on by Messrs. Butto Kristo Paul & Co. of Calcutta.

"I" or the rosin clarified by crystalline alum was sent to the Imperial Institute, London, for valuation. According to the report of the Imperial Institute, London, on this sample, which is given below, it is valued in London at Rs. 9-12 to Rs. 10-4 per cwt. It is not, therefore, clear to the writer how the rates quoted for it in the Indian market are so low.

Report on alum clarified Colophony from Imperial Institute, London, No. 34745, dated 7th January 1911.

Reference.—Letter No. 465—110, dated 23rd June 1910, from the Assistant Imperial Forest Chemist at Dehra Dun.

Number or mark and weight of sample.—"Colophony prepared at Naini Tal by using crystalline alum for its clarification." Weight $2\frac{1}{2}$ lbs.

Description.—The sample consisted of masses of pale brownish-yellow resin having the usual appearance and properties of colophony of good quality.

Results of Examination.

Moisture	0·80 per cent.
Ash	0·15 ,,
Melting point (determined on the powdered resin in a capillary tube).	74° C.
Acid number (milligrams of potassium hydroxide required to neutralise one gram of resin).	174
Saponification number	184

The ash yielded by the resin was a reddish-brown powder; the quantity obtained was insufficient for detailed examination.

The analytical results show that this colophony is of good quality.

Commercial valuation and remarks.—Samples of the colophony were submitted to merchants, who valued it at £14 to £15 per ton in the United Kingdom, and to a firm of soap-makers, who considered it to be worth £13 per ton. The current value of American rosin of similar quality was £14-9-0 per ton. The merchants stated that the present prices are abnormally high and that £12 per ton could be regarded as a fair average price for this material.

This Indian colophony is of much better quality than the previous sample examined at the Imperial Institute and dealt with in the interim report on Indian turpentine, dated 27th July 1909 (see below). As explained in that report, the value of rosin depends primarily on its colour, provided that the composition of the material as indicated by the usual constants is satisfactory.

The present sample is not quite so pale as the best Bordeaux rosin, but it would be classed with the "Water White" grades of American rosin. There is no doubt that Indian rosin of this quality would sell readily in the United Kingdom at good prices * *

Extract from the Interim Report on Indian Turpentine, dated 27th July 1909, by Professor W. R. Dunstan, M.A., F.R.S., Director, Imperial Institute, London.

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Rosin and Colophony.

The following specimens of colophony have been examined:—

(*a*) Colophony of *Pinus longifolia* from Naini Tal, United Provinces.

(*b*) Colophony prepared in the Imperial Institute from the crude turpentine from Naini Tal, United Provinces.

(*c*) Colophony prepared in the Imperial Institute from the crude turpentine of *Pinus excelsa* from the Punjab.

(*d*) Colophony prepared at the Imperial Institute from the crude turpentine of *Pinus Gerardiana* from the Punjab.

The specimen of the colophony of *Pinus longifolia* from the Punjab was very similar to (*a*) above, and was not examined. The results of the examination are given in the following table:—

——	(*a*)	(*b*)	(*c*)	(*d*)
Melting point	75°—78° C.	..	..	..
Specific gravity	1·067	..	..	..
Ash, per cent.	0·125	..	..	..
Saponification value *	190·0	193·0	194·0	176·0
Acid value	165·0	170·1	170·0	174·0
Unsaponifiable matter, per cent.	5·0	3·8	9·0	6·9
Specific rotation (α) D	9° 40′	*Nil*	—4° 48′	11° 20

* Milligrams of potash per gram of colophony.

For comparison with these results the following figures obtained for typical samples of the American and Bordeaux colophonies of commerce may be quoted:—

——	American.	Bordeaux.
Saponification value	184·0	184·0
Acid value	175·6	175·0
Unsaponifiable matter, per cent.	6·5	*Nil*
Specific rotation (α) D	29° 5′	*Nil*

The results of the examination show that there is little difference in composition between the Indian colophony and that procured from the United States and France. The Indian sample (*a*) from Naini Tal was rather dark in colour, and for that reason would rank as of low grade, but there appears to be no reason why, if reasonable care is exercised in the collection of the crude turpentine and in its distillation, a pale-yellow rosin should not be produced in India.

Commercial Valuation of Indian Colophony.

Samples of the first three rosins, *viz.*, (*a*), (*b*) and (*c*) referred to above, were submitted to rosin importers and to soap-manufacturers, for valuation and trial. The former reported that (*a*) would be worth £7 per ton, (*b*) £8 per ton, and (*c*) £12 per ton. The soap-makers stated that (*a*) and (*b*) would be too dark for their purposes, but might be suitable for use in paper manufacture and for that purpose would be worth from £9 6*s*. to £10 per ton, whilst (*c*) would be suitable for soap-making and worth £11 per ton in this country. * * *

CONCLUSION.

In conclusion the following recommendations for the clarification of Indian rosin prepared by whatsoever process may advantageously be summed up:—

(1) As is done in France and America, great care should be taken to avoid the admixture of accidental impurities in the preliminary stages of collection of the crude resin. This can be done by keeping the area round the tree under tapping free of pine needles, leaves, etc., and by collecting the resin as it exudes from the tree in covered receptacles. The crude resin should be transported to the factory in covered vessels made of corrugated iron sheets in sizes convenient for transport.

(2) The crude resin should be classified in different grades according to its colour and quality, which will depend, as said elsewhere, on the season and the number of years over which tapping has been continuously carried out. The colophony resulting from the various grades of resin should be properly graded before sending to the market.

(3) Melted rosin as it issues from the still must always be heated over an open fire to drive off the last traces of the oil. Colophony, as produced in the Government Factory at Bhowali, is sticky and is coloured greenish by copper salts from the still. The open fire heating will free it from the last traces of oil and make it harder. It will be less liable to melt in transit. It will have a brighter appearance. While heating it over an open fire, it is preferable to gradually add about 5 lbs. of water to a charge of about 2 mds. of colophony. Even if light coloured colophony is not required, it must undergo this treatment.

(4) Rosin of darker qualities while being heated over an open fire should always be treated with crystalline alum as described above and if necessary after clarification exposed to sunlight for further bleaching.

(5) It will be seen that any desired shade of colour can be given to colophony by clarifying it with a mixture of alum or nitre or both, and the shade in demand can be obtained by varying the proportion of the clarifying mixture.

(6) Iron vessels are not to be used for handling hot rosin.

(7) If possible, it will be best to have a thick coating of tin inside the copper stills to avoid initial discolouration.

(8) Last but not the least, it is essential that in order to produce the better qualities of rosin, the still should be skilfully "cut" as is done in America and France, and if this be done, not only is the quality of the colophony improved, but also that of the turpentine as well.

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PART I.

On the Parasitic Hymenoptera reared at Dehra Dun, Northern India, from the Lac (*Tachardia*) and Sal Insects.

By P. CAMERON.

Introduction.

IN this paper I have enumerated and described the Insects sent me by Dr. A. D. Imms, Forest Zoologist, from Dehra Dun, where they were mostly reared or collected by himself. The most important, as they may prove to be of economic importance, are those reared from the Lac and Sal Insects. There can be no doubt that the small insects belonging to the Chalcid groups of the *Aphelinæ* and *Encyrtinæ* are direct parasites of the Lac and Sal Insects, but as regards some of the other *Chalcididæ* and the *Braconidæ*, it is probable that they prey on moth larvæ which feed on the Coccids. That a Tineid larva does feed on the lac insects is certain from the observations of Mr. E. E. Green (*cf.*, *Proc. U. S. Nat. Mus.*, XVIII, 633) in Ceylon.* If it be the case that they destroy Tineid larvæ which kill the Lac insects they, *i.e.*, the Braconidæ, etc., must be looked upon as beneficial insects, while the *Encyrtinæ* and *Aphelinæ* are injurious, as they kill useful insects. From the systematic point of view the most interesting is the species of *Cyclopleura*, of which I had received a species from Borneo previously.

As bearing on the Lac Insect, it may be useful to note that Mr. E. E. Green reared from *Tachardia albizziæ* in Ceylon: *Encyrtus tachardiæ*, How.; *Anastatus tachardiæ* How. (*Eupelminæ*); *Holcopelte*, sp. (*Entedoninæ*); *Tetrastichus*, sp. (a hyperparasite no doubt); *Bracon greeni*, How. and *Aphrastobracon flavipennis*, How., the last two being probably parasitic on moth larvæ.

* Two species of Lepidoptera, *e.g.*, *Eublemma amabilis* and *Holocera pulverea* are common parasites of *Butea* lac in India. A. D. Imms.

The lac was obtained by Mr. R. S. Troup from Bishanpur in the Saharanpur District, and a number of trees of *Butea frondosa* were infected with it. The experiments were carried out at Ranipur in the Siwalik Forest Division. Samples of the lac were sent from time to time by Mr. Troup to the Forest Zoologist at Dehra Dun who reared the parasites described in this paper.

CHALCIDIDÆ.

Chalcidinæ.

Centrochalcis, gen. nov.

Antennæ, 11-jointed, placed opposite the end of the eyes, slender, of uniform thickness, the scape narrow, reaching to the ocelli. Eyes bare; the malar space not quite so long as them. Apex of scutellum rounded. Metanotum with the sides broadly rounded, without projections—abdomen sessile, the basal segment as long as the following 3 united—about one-third shorter than the others united; the ovipositor broad, nearly as long as the abdomen. Hind femora with about 10 short, blunt, clearly separated teeth, which are almost hidden by the dense hair. Apical nervures thick; the stigmal curved, as long as the post-stigma, which is gradually narrowed towards the apex. The abdomen in the ♀ ends in a stout, broad stylus, which almost, or quite, equals it in length. Head, thorax and legs and the apices of the abdominal segments densely covered with silvery pubescence. There is only one ring joint in the antennæ; it is bare; the flagellar joints are elongate. Malar space half the length of the eyes. Base of abdomen rounded.

The antennæ are not placed quite so high up on the face as in some species of the group, but the genus can hardly be placed in the *Haltichellini*. In the arrangement of Ashmead (*Mem. Cairn. Mus.*, i, 248) it would run near to *Trigonura* and *Thaumatella*, both neotropical genera, with which it cannot be confounded.

Centrochalcis ruficaudis, sp. nov.

Black, densely covered with longish glistening white pubescence, the abdominal segments fringed with longish white hair; a band on the apex

of pronotum broad laterally, narrowed in the centre, a line along the sides of the mesonotum, a broader one on the sides of the scutellum and the ovipositor, except at the base and apex above, dark rufous; the apices of the abdominal segments of a darker red; the under side of the flagellum of the antennæ, and its basal joints above, rufous; the pedicle black; legs black, densely covered with white pubescence, the anterior obscured with rufous, the middle femora, tibiæ and tarsi rufo-testaceous; the hinder tarsi appear white from being densely covered with white pubescence. Tegulæ rufous, wings clear hyaline, the nervures black. Head, pro-and mesothorax coarsely rugosely punctured, the head more finely than the thorax; the pronotum more finely than the mesonotum and the latter less coarsely than the scutellum—Propleuræ coarsely rugosely punctured; the basal half of the mesopleuræ rugosely punctured, thickly covered with longish white hair, the apical half depressed, flat, shining, bare, closely, rather strongly striated, the striæ stronger above than below. Metapleuræ coarsely reticulated-punctured. Metanotum irregularly reticulated; a small angled area in the centre of the base, with a large, irregular, almost semicircular one on either side of it, these bearing some irregular striæ. The 1st abdominal segment is punctured to near the apex, the others are punctured at the apex where the pubescence is, the apical are more coarsely punctured throughout. Ovipositor strongly punctured at the base, weakly at the apex. The hind femora closely denticulate throughout; the teeth are small, rounded and almost hidden by the dense pubescence. ♀ and ♂.

Length ♀ 6 mm., ovipositor 2 mm., ♂. 4 mm. Dehra Dun, June, "Out of sundri wood." (*Heritiera Fomes*, Buck.). The ♂ has the antennæ entirely black, the sides only of the pronotum are rufous, the central red line being almost obliterated; the mesonotum bears no red, and the ventral surface of the abdomen is red; the 4 front legs and the hind tarsi are rufous. Probably the amount of the red colour varies in both sexes. In one ♂ I can only count 9 distinct femoral teeth.

Chalcis tachardiæ, sp. nov.

Black, densely covered with white pubescence, the apex of the femora, base and apex of tibiæ more broadly and the tarsi yellowish white, as are also the tegulæ; wings clear hyaline, the nervures black. Hind femora with about 10 small teeth; the apical 3 smaller than the rest,

the 4th longer and more slender; the following 3 stouter, longer, triangular; the next two shorter, widely separated, bluntly rounded, the basal larger, longer, the apex depressed. Apex of scutellum broadly rounded, distinctly margined. Metanotum closely reticulated, without a distinct areola; the basal row of equal width, margined behind, the outer reticulations are larger than the central; the sides of the metanotum are broadly rounded. Abdomen not quite so long as the thorax, gradually narrowed to a sharp point from the apex of the 2nd segment, the 3rd and following segments densely covered with silvery hair—Sheath of ovipositor short, broad, acutely pointed at the apex, not projecting much. Frontal depression very smooth, bare and shining; there is an indistinct short triangular keel on the top. Temples narrow, margined. Between the antennæ and clypeus is a smooth plate, obliquely narrowed above and below, the lower part narrower than the upper. Clypeus smooth, except for 4 foveæ. Wings clear hyaline, the nervures black; the stigmal branch short, thick, narrowed slightly at the base, about twice longer than thick. The post-marginal vein twice its length. Antennal scape and pedicle, bare, shining, the flagellum opaque, densely covered with white pubescence. ♀.

Length 2·5 to 3 mm.

"Out of Lac." November. It is probably a parasite on a moth caterpillar feeding on the Lac insects.

Toryminæ.

Paroligosthenus, gen. nov.

Eyes pilose. Scutellum with a transverse furrow near the apex, the part beyond it smooth. Metanotum with a keel down the centre. Apical margins of basal abdominal segments, not incised. Hind femora with one small tooth close to the apex; the hind spurs one-third of the length of metatarsus. Antennæ with one ring joint. Stigmal branch thickened, narrowed at the base, the apex cleft; it is placed in a narrow cloud; the post-marginal vein about one-third longer than it; the marginal one-third of the length of the basal. Mesonotal furrows distinct. Scutellum large, pyriform, the narrowed end at the base. Mesopleuræ with the base above separated by a furrow into a triangular

area having a foveainits centre; it is not otherwise excavated. Occiput not margined.

The only genus of *Monodontomerinæ* known with pilose eyes is *Oligosthenus,* Foer., but that has not a cross-furrow on the scutellum and differs in other respects. The pilose eyes separate it from the genera with a transverse scutellar furrow, *Physothorax* and *Pleseostigma* being further distinguished from it by the 1st abdominal segment being incised medially. It is more closely related to *Monodontomerus,* but that genus has bare eyes.

Paroligosthenus trichiopthalmus, sp. nov.

Green, with coppery and brassy tints, the apical segments of the abdomen rufo-violaceous, the antennal scape, pedicle, tibiæ and tarsi rufo-testaceous, the flagellum of antennæ black, fuscous below; wings hyaline, the nervures black. ♀.

Length 3 mm.; terebra 1 mm. or one-third of the length of the abdomen.

Dehra Dun. Out of Sal (*Shorea robusta*) and out of Sundari wood (*Heritiera Fomes,* Buck.) May and June.

The puncturation is weak and shallow on the thorax, there are indications of fine transverse striæ on the pronotum; the base of the apical part of the scutellum is finely and closely longitudinally striated. There is a triangular area on the base of the metanotum in the centre formed by furrows. Mandibles dark rufous. The basal half of the 2nd abdominal segment is finely and closely transversely striated. The pubescence on the head, thorax and legs is white and dense; the abdominal segments are fringed with longer white hair. There is a fine keel on the malar space, which is one-third of the length of the eyes. The clypeus is clearly separated, is narrow above and becomes gradually roundly widened below. The basal joint of the flagellum is obscure green above; it is longer than the ring joints; the flagellar joints are densely covered with white pubescence.

The host of this species is not known, but it was bred from a cocoon collected out of a Sal tree, the cocoon being probably that of a moth. The European species of *Monodontomerus,* its closest ally, are known to be parasitic on *Anthophora* (a bee), caterpillars of moths and a sawfly.

Cyclopleurinæ.

Cyclopleura, gen. nov.

Head transverse behind, broadly rounded in front, the temples hardly developed, malar space distinct, one-third of the length of the eyes, which are narrower below than above. Antennæ placed immediately over the clypeus and below the eyes, their joints longish, the apical ending in a sharp point. Pronotum as long as the top of the head, gradually narrowed from the apex to the base. Mesonotum large, longer than wide, rounded at base and apex, without furrows. Scutellum large, as wide as long, rounded at base and apex, flat. Post-scutellum large, triangular, projecting over the metanotum, which is flat, large, its apex broadly rounded. Metapleuræ large, semicircular, projecting beyond the metanotum and on to the basal abdominal segment; the projection is thicker above than at the apex and below. Abdomen longer than the head and thorax united, gradually narrowed to a sharp point, the basal segment longer than the 2nd, the others of almost the same length. Legs long, the coxæ and femora large, thick, the latter flattended below, longish oval; tibiæ longish, spinose, the spurs of moderate length; the middle and hinder with 2; the tarsi longer the tibiæ, closely spinose the apical joint minute. The submarginal, marginal and post-marginal veins form one piece; there is no stigmal branch; there is a distinct marginal vein in the hind wings; it is lighter coloured in the centre than on the margins; wings are long and narrow and are placed on the middle of the thorax—a narrow furrow with 3 angled curves runs down the centre of the mesopleuræ, this furrow being more distinct than that which separates them from the metapleuræ; there is no mesosternal furrow. The antennæ are probably 9-jointed, but owing to the manner in which they are covered with gum I am not certain as to the exact number, nor can I make out the structure of the mandibles, except that they are broad and rounded at the apex. I cannot refer the type of this genus to any of the recognized tribes; in my opinion it should form the type of a new one: the peculiar structure of the metathorax, the large triangular post-scutellum, the long narrow wings with the nervures in one piece, the longish, sharp-pointed abdomen and the long spiny legs with their large coxæ and stout femora appear to warrant this. For the present I should place the tribe near the *Toryminæ*.

I am acquainted with 2 species, one of them being a parasite of the Lac insect in India. The differences between the 2 may be shown thus:

Wings smoky, the hind femora black, the abdomen not banded . *fumipennis*
Wings hyaline, the hind femora not black, the abdomen with testaceous bands. . . . . *claripennis*

Cyclopleura fumipennis, sp. nov.

Black, the mesonotum blue, the scutellum dark purple, the post-scutellum yellow; the basal ventral abdominal segment testaceous; the front legs, the 4 hinder trochanters and the 4 hinder tibiæ and tarsi and the antennal scape, pallid yellow; wings hyaline to near the middle, dark fuscous beyond, the cloud becoming gradually obliquely narrowed from the hinder margin to the costa, which is pale in the lighter coloured basal part. Smooth, shining, the mesonotum densely covered with black pubescence, the base of the scutellum with a few long hairs, as have also the apical abdominal segments. ♀.

Length 2·5 mm.

Kuching (John Hewitt, B.A.)

The ovipositor has a broad, pilose sheath and projects slightly beyond the apical segment. The apex of the middle coxæ reaches to the apex of the 1st abdominal segment, the 3rd to the apex of the 2nd.

Cyclopleura claripennis, sp. nov.

Antennæ black, the head dark purple, the thorax dark blue, the abdomen black, the basal segment narrowly blue at the base, almost the apical half of the 2nd and 3rd segments and the base of the 2nd narrowly in the centre, more broadly laterally, and the greater part of the basal 4 ventral segments rufo-testacous; legs pallid yellow, the femora above, and the tibiæ above and below, narrowly lined with black; the tarsi are darker coloured than the tibiæ; both are densely covered with short, blackish hair. Wings hyaline, the nervures pale, there is a small faint triangular cloud at the stigmal vein; the surface is densely pilose and the edges are fringed with short hair. ♀.

Length 2·5 mm.

Bred from Lac.

Smooth and shining, except the mesonotum which is finely, closely punctured, almost as if reticulated.

Eurytominaæ.

Eurytoma pallidiscapus, sp. nov.

Black densely covered with white pubescence, the antennal scape, trochanters, more than the apical half of the anterior femora, apical third of middle and apical fourth of posterior, the tibiæ and tarsi pale testaceous, the tibiæ at the base behind tinged with fulvous; wings hyaline, the nervures whitish testaceous. ♀.

Length 2 mm. Dehra Dun. Out of Lac. November.

Head and thorax umbilically punctured, the mesonotum more strongly than the head, the propleuræ less strongly punctured, the punctuation becoming gradually weaker below, where it is bounded by a stout, rounded keel; mesonotum with a longish triangular, smooth and shining space above, the apex irregularly longitudinally striated. Metapleuræ coarsely rugosely punctured, bounded at the apex by an irregular keel, beyond which it is irregularly reticulated above, below smooth with 3 or 4 stout irregular striæ. Centre of metanotum with 3 longitudinal keels, the outer stouter and diverging above; between them are a few irregular transverse striæ; the rest closely, finely, but distinctly punctured, almost reticulated, the top and sides with a row of areæ, the top with an upper row of stronger areæ. The mesopleura is divided into 3 parts by 2 keels, the basal keel is shining and shorter than the middle or posterior; there is a fine keel at the apex of the apical crenulated furrow. Hind coxæ opaque, sparsely covered with long, soft white hair; closely and finely reticulated. Stigmal nervure long, slightly dilated at the apex, narrower and almost as long as the post-marginal vein.

Eupleminæ.

Brasema annulicaudis, sp. nov.

Dark green tinged with brassy, the head in front and the pleuræ largely violaceous, the abdomen entirely violaceous, the antennal scape fulvous, the flagellum black; the fore legs dark blue, the tibiæ below and their apex and base above and the tarsi testaceous, the middle legs testaceous, their femora infuscated; the hinder testaceous, their coxæ

except at the apex, the femora and slightly more than the basal half of the tibiæ, black; wings hyaline, the nervures pale testaceous; ovipositor half the length of the hind tarsi; broadly banded with white, the black basal part half the length of the apical; the spurs are almost white; the spines on the underside of the middle tarsi black. ♀.

Length 2 mm.; terebra ½ mm.

Bred from Lac in November.

The marginal vein is slightly longer than the submarginal and is thickened at the apex; the stigmal branch is a little thickened at the apex where there is a short projection on the upper side. Parapsidal furrows distinct, as is also the transverse furrow at the base of the scutellum. Abdomen not quite so long as the thorax; its apex broadly rounded. In certain lights the flagellum of the antennæ is seen to be metallic blue. The pubescence is short, sparse and white. The antennal scape does not reach to the ocelli; the 3rd and 4th joints are about equal in length; the apical are dilated and compressed.

A species of an allied genus of *Eupelminæ, Anastatus tachardiæ,* Howard, is, in Ceylon, parasitic on *Tachardia albiziæ.*

Encrytinæ.

Lissencyrtus, gen. nov.

Slender, as long as the head and thorax united, antennæ, clearly separated from the apex of the clypeus, opposite the lower edge of the eyes, the scape slender, longish, not quite half the length of the flagellum, not reaching to the ocelli; the pedicle about 3 times as long as thick, the 2nd joint of flagellum nearly as long as it, the next twice longer than thick, the following about as long as thick, the apical 4 forming a club, not very clearly separated. Ocelli in a triangle, the lateral close to, but not touching the eyes, which are large, hardly converge above and are separated above by twice the length of the antennal pedicle. Malar space half the length of the eyes, a narrow, but distinct furrow down it. Front, face and clypeus continuous, forming a broad rounded keel. Labrum only visible when viewed from below. Mandibles short, broadly rounded at the apex; the teeth indistinct. The front forms a triangular depression in the centre. Mesonotum as long as the scutellum, which becomes gradually narrowed

from the base to the apex; it is slightly longer than it is wide at the base; there is a distinct transverse furrow at the base; the ancillæ are longish transversely triangular. The mesosternum is bounded, on the outerside, by a distinct furrow. Abdomen not quite as long as the thorax, broadly triangular, from the base of the 2nd segment, becoming gradually narrowed, the back depressed; the ovipositor projecting distinctly. Front and vertex with weak scattered punctures; the thorax smooth and shining, almost bare; the abdomen is more shining than the thorax. Apex of wings shortly ciliated; the marginal vein about twice longer than thick, shorter than the stigmal with which it forms an acute angle, the stigmal vein is knobbed at the apex, the post-marginal vein is thickened at the base, and becomes gradually thinner. The head is metallic, but not the thorax, the abdomen is less metallic than the head. The head, seen from the front, is as wide as long; the few punctures on it are thimble-like. The apical 3 antennal joints, seen laterally, appear in some examples, to form a 3-jointed club.

In Ashmead's classification this genus comes nearest to *Hymencyrtus* and *Coccophoctonus*, both of which may be known by the eyes being pilose. Compared with Ashmead's figure of the former, the scutellum is larger, and does not become narrowed towards the apex and is more distinctly longer compared with the width at the base, the abdomen, in the figure, is shown to be longer, and the antennæ more robust; the pronotum, too, is larger. In shape it is more like Ashmead's figure of *Parencyrtus*, but that genus has hairy eyes.

Lissencyrtus troupi, sp. nov.

Thorax and legs reddish orange, the latter paler than the former, the head dark blue, the mandibles and palpi reddish testaceous, the pronotum of a dark, the base of the mesonotum of a bright metallic blue, the abdomen dark violaceous; antennæ testaceous, the scape lighter in tint, more yellowish than the flagellum; the apical club fuscous; wings hyaline, the nervures fuscous, the margin shortly fringed. Entirely smooth, shining, the mesonotum covered sparsely with a short blackish pile. ♀.

Length 2 mm.

Dehra Dun; bred in November out of Lac.

Antennæ as long as the head and thorax united, not much dilated towards the apex, the apical joints not forming a club ; the pedicle not quite 3 times longer than wide. Ocelli in a large equilateral triangle, the hinder clearly separated from the eyes ; these are of equal size. Malar space about as long as the eyes ; it is, as is also the outer-side of the clypeus, finely, but distinctly, punctured ; the clypeus is bluntly keeled down the middle.

Copidosoma ? clavicornis, sp. nov.

Black, the head tinged with bluish-violaceous, the mesonotum darker coloured than the scutellum, which is distinctly brassy, the pleuræ coloured like the mesonotum, the abdomen violaceous, distinctly blue-tinted at the base, the antennæ with the scape yellowish testaceous, the flagellum fuscous, legs fulvo-testaceous, the base of the coxæ broadly, the base of the femora and a broad line on the outside of the tibiæ nearer the base than the apex, black ; wings hyaline, the nervures fuscous.

Length nearly 2 mm.

Dehra Dun. Bred from Lac.

Shining, the abdomen more so than the thorax, smooth, the scutellum finely and closely punctured, the punctures only visible with a good magnification, the sides apparently closely, finely transversely striated. Mesonotum closely, the scutellum more sparsely covered with longer black hair. There are a few scattered punctures on the front. The front ocellus is separated from the hinder by a greater distance than these latter are from each other ; they almost touch the eyes, which are slightly longer than the malar space. Antennal scape about two-thirds of the length of the flagellum ; it does not reach much above the bottom of the eyes ; the flagellum stout, thickened towards the apex, the pedicle is about 3 times longer than wide ; the other joints of the flagellum are as wide as long ; the apical 4 joints form a club but not a very prominent one ; the apical 2 joints are smaller than the preceding 2. The abdomen forms a longish triangle, it becoming gradually narrowed from the base to the apex ; it is shorter than the thorax, the ovipositor distinctly projects and has a broad sheath.

The pronotum is small, the scutellum large, triangular, becoming gradually, rather roundly narrowed from the base to the apex, longer

than it is wide at the base ; the basal bordering furrow is shallow, but distinct. The antennæ and legs are covered with short white, close pubescence. Wings ciliated, the marginal vein thickened, about twice longer than thick, about one-third of the length of the stigmal.

As I am not quite certain if this species is a true *Copidosoma* I give a generic description of it. The sculpture is certainly weaker than in that genus, in which the front and vertex are stated to be thickly and sharply thimble-like-punctured, while in the species I have described there are only a few that could be so described. The puncturation, however, seems to vary ; probably some specimens are more mature than others. Antennæ placed half way between the eyes and the apex of the clypeus ; the scape one-third of the length of the flagellum, which is dilated towards the apex, the apical third forming a compressed club ; pedicle twice longer than wide, eyes distinctly converging above, the malar space about one-third of their length. Ocelli in a longish triangle ; the hinder separated from each other by a clearly greater distance than they are from the eyes. The lower part of the front face and clypeus form a raised longish conical continuous projection, the narrowed part above, the apex almost obliquely depressed, transverse, the middle keeled. Mesonotum nearly as wide as long, slightly longer than the scutellum, which is larger, a little longer than it is wide at the base, gradually roundly narrowed to the apex, which is rounded and one-third of the width of the base. Post-scutellum convex, keeled at the base and apex, the latter roundly narrowed. Abdomen not quite so long as the thorax, triangular, becoming gradually narrowed from the base to the apex, the base with a broad, rounded keel, the back largely depressed ; the ovipositor broad, as long as the longer middle spur. Marginal nervure thickened, about 4 times longer than thick, as long as the stigmal vein, which is curved and is thickened towards the apex. Apex of wings ciliated shortly and closely. In the ♀ the antennal joints are not much longer than wide, the flagellum is closely pilose ; the antennæ are as long as the head and thorax united ; the 1st joint of the flagellum is not much longer than the 2nd ; in the ♂ the flagellum joints are much longer compared with the width, are more clearly separated and are densely covered with long hair, almost as long as the joints, and which forms a fringe on the outerside, the abdomen is triangular as in the ♀ ; but is slightly shorter. The whole body is shining ; the head and thorax are weakly sparsely punctured.

Alphelinæ.

Hadrothrix, gen. nov.

Antennæ 8-jointed, the club 3-jointed, not quite so long as the preceding joints united, the scape short, not reaching to the ocelli; the basal joints to the club armed at the base with a long stiff bristle, which is longer than the joint; the antennæ originate from shining tubercles placed clearly above the lower part of the eyes. Head compressed laterally, lenticular, transverse behind, the temples only very slightly developed. Wings shortly closely ciliated, without a transverse hair line; marginal vein thicker and clearly longer than the submarginal; stigmal vein thin longish, about one-fourth of the length of the marginal. Parapsidal furrows clearly defined. Scutellum wider than long, transverse at the base, base broadly rounded at the apex.

In the "Revised Table of Genera" given by Dr. L. O. Howard, (Technical Series, No. 12, Part IV, U. S. Dept. of Agric., 1907, p. 71), this new genus runs to *Aneristus* and *Crecophagus*. Characteristic are the long, stiff bristles on the antennæ and the long, thin stigmal vein, which is longer than in any of the described genera. There are no stiff bristles on the hind tibiæ behind. The thin head is somewhat as in *Prospalta murfeldti* as figured by Howard, (l.c., p. 39), but is more transverse behind.

Hadrothrix purpurea, sp. nov.

Dark purple, shining, the basal segment of the abdomen, except the centre of the basal slope, dark testaceous; the antennæ dark testaceous, the apex of femora, the tibiæ and tarsi whitish yellow; wings clear hyaline, the nervures pallid testaceous, the apex fringed with long ciliæ. ♂

Length 1 mm.

Dehra Dun. Bred out of Lac.

Scelionidæ.

Caloteleia rufipes, sp. nov.

Black, the antennal scape, basal, narrowed joints of the flagellum, apical half of basal abdominal segment and the legs, red; wings hyaline,

the marginal vein black, the sub-marginal and stigmal paler. Head and thorax opaque, smooth, the abdomen smooth and shining. Antennal scape as long as the club, the basal narrowed part of flagellum shorter, the 2nd and 3rd joint narrowed at the base, the pedicle of equal width. ♀.

Length 1 mm.

Dehra Dun. At light. 5th September (*V. S. Iyer*).

Caloteleia was formed on a species occurring in fossil gum copal. The species described above may belong to a different genus, but it appears to belong to *Caloteleia*, Brues, (Gens. Ins. *Sceleonidæ*, 32). *C.f.* Keiffer, *Ann. de la Soc. Scientifique de Bruxelles*, XXXII, (2) 122. I give a generic description of it.

Antennæ placed close to the mouth, the scape above stout, about one-third of the length of the flagellum; pedicle narrowed at the base, twice longer than wide, the apical 6 joints forming a stout, clearly separated club. Head large, wider than the thorax, rounded in front, not quite transverse behind; the lateral ocelli placed close to, but not touching the eyes. Parapsidal furrows absent. Scutellum not much raised, wider than long. Post-scutellum small, flat. Metanotum small, flat, its sides margined. Abdomen longer than the head and thorax united, its basal segment forming a raised rounded tubercle, projecting on to the metanotum and with a straight oblique slope towards the apex, the basal tubercle becomes narrowed gradually towards the apex, which is flat above and of equal width; it is twice longer than wide; the 2nd is wider than long, the 3rd is the largest and is square. Marginal vein twice longer than thick, punctiform; the post-marginal distinct, hardly so long as the stigmal which is dilated at the apex.

Immsia, gen. nov.

Antennæ placed close to the mouth, the scape as if 2-jointed, the apical part thicker and twice the length of the basal, the 2 being clearly separated; the flagellum 10-jointed, the pedicle twice longer than thick, the following joint is twice its length, the apical 5 joints in the ♀ form a club. Lateral ocelli received close to the eyes. Head wider than the thorax, the temples short, the occiput curved inwardly. Scutellum large forming a semicircle transverse at the base, the apex rounded.

Post-scutellum large, unarmed, wide, metanotum short, the sides at the base bordered by a stout keel. Abdomen in ♀ shorter than the

thorax, broadly ovate, almost as wide as the thorax, the 2nd segment as large as all the others united, as wide as long, the base crenulated, the rest closely longitudinally striated to near the apex. The sub-marginal and marginal nervures are not clearly separated; the former is curved, the latter straight, not half its length; the stigmal vein is long, almost as long as the marginal; the post-marginal is longer than the stigmal.

There are no parapsidal furrows. The edges of the abdomen are somewhat acute, but can hardly be called keeled; the ovipositor does not project. The outer eye orbits and the malar space bear a stout keel; there is also a keel down the middle of the front. The keel on the malar space is curved and reaches to the base of the mandibles. Malar space longer than the eyes. Clypeus short, its apex rounded, broadly margined. Legs normal, the femora not dilated, the hind tarsi slightly larger than the tibiæ, 5-jointed, the basal joint of the hinder as long as the following 2 united. Mesonotum bordered laterally by a crenulated furrow. Prothorax small, not visible from above.

A genus easily recognised from anything known by the peculiar form of the antennal scape, which looks as if it were 2-jointed from the base, being abruptly narrowed.

Immsia carinifrons, sp. nov.

Black, the dilated apical part of antennal scape and the legs, except the coxæ, red, the basal joints of the antennal scape of a duller red; wings hyaline, the edges shortly ciliated, the nervures pallid. ♀.

Length 2 mm.

Dehra Dun, 3rd August (*V. S. Iyer.*)

Head and thorax opaque, closely rugosely punctured, the basal segment of abdomen strongly, longitudinally striated, the large 2nd finely and more closely to near the apex, the rest smooth and shining. Vertex closely rugosely punctured, the front transversely striated, the striæ in the centre stouter, more clearly separated and more or less curved; a stout keel down the centre. Cheeks margined, aciculated. Mesonotum closely, distinctly longitudinally striated, the striæ, interlacing; scutellum strongly longitudinally striated, the striæ almost forming reticulations. Scutellum strongly, irregularly striated. Metanotum strongly, regularly striated. Propleuræ irregularly longitudinally striated. Mesopleuræ aciculated, its base and apex with a row of foveæ, that on

the apex, more regular and stronger than the base. On the upper, basal half of the metapleuræ is a large earshaped area formed by smooth, shining keels; in its centre is a smooth keel; at its apex are 2 small semicircular areæ; the rest is irregularly reticulated. The ventral surface of the abdomen is more roundly convex—not so flat—as the dorsal; the apical 4 segments are of almost equal length.

Evaniidæ.

Evania appendegaster, Lin.

Schletterer, *Ann. K. K. Hof. Mus., Wien*, IV, 136; Bradley, *Trans. Am. Ent. Soc.*, XXXIV, 139.

Suraj Bagh, Dehra Dun. August. A common, cosmopolitan parasite of the cockroach.

BRACONIDÆ.

Braconinæ.

Bracon tachardiæ, sp. nov.

Rufo-testaceous, the legs paler, distinctly yellowish in tint, the antennæ metanotum and the 3rd and 4th dorsal segments of the abdomen, except narrowly on the sides, black; wings hyaline, iridescent, the costa, parastigma, stigma and nervures fuscous, the costa and stigma round the edges darker coloured, the apical nervures paler than the basal; the 2nd transverse cubital nervure fully one-third the length of the 2nd abscissa of radius. ♀.

Length 2 mm.; ovipositor 1 mm.

Bred from *Tachardia* (lac).

Antennæ 23-jointed in ♀ The ♂. has the mesothorax for the greater part black; the basal segment may be paler, more yellowish than the others. The 2nd and 3rd abdominal segments are finely, closely punctured, the former more strongly so than the latter; there is a not very distinct keel down the centre of the 2nd segment, its base slightly dilated, the suturiform articulation narrow, obscurely striated and without a lateral apical branch. In the ♂ the vertex, occiput and the apical dorsal abdominal segments may be black, in the ♀ the abdominal black marks vary in extent; there may be only narrow transverse lines

on the 2nd and 3rd segments, or the 2nd and following segments may be entirely black above. It is probably a common and variable species.

Iphiaulax sal, sp. nov.

Black, the basal 3 ventral segments, white; wings fuscous, the anterior paler to the transverse median and transverse cubital nervures, the stigma and nervures black, the 3rd abscissa of the radius fully larger than the basal two united; palpi white, covered with longish black hair, the base of the maxillary blackish. Head and thorax smooth, shining sparsely covered with longish black pubescence, the face and metanotum with the pubescence white. Tibiæ and tarsi densely covered with short white pubescence, the femora and coxæ more sparsely with longer white hair; the spurs are black. Abdomen longish oval, as long as the head and thorax united and clearly wider than the thorax; the 1st segment with the basal slope smooth, shining, bordered by wide oblique crenulated furrows, the apex is raised in the centre, closely, deeply reticulated punctured, bordered laterally by a stout keel which unites to the outer edge of the segment at the base. The 2nd segment in the centre is deeply, closely reticulated-punctured, margined outwardly and of equal width, its outer edge with some oblique striæ; the central area smooth longish triangular, twice longer than it is wide at the base, the outer edge irregularly longitudinally striated. The 2nd segment, closely, strongly sharply striated, the striæ slightly converging towards the centre. Suturiform articulation narrow, crenulated, converging towards the middle and without an outer apical branch. The 3rd and 4th segments are more finely, regularly and closely striated and are without oblique or transverse furrows. Sheath of ovipositor thickly covered with short white pubescence and thickened towards the apex. ♀.

Length 5 mm.

Kaluwala, near Dehra Dun, 3rd December, on Sal leaf.

Temples wide, nearly as long as the eyes above, the occiput transverse. Parapsidal furrows narrow, but clearly defined. Face opaque, closely punctured, densely haired. Mandibles rufo-testaceous, black round the edges.

Iphiaulax Immsii, sp. nov.

Rufo-luteous, the abdomen and legs paler in tint than the thorax; the antennæ and mandibles black; wings fuscous, yellowish hyaline to

the transverse basal and transverse median nervures; the part outside paler; there is a small conical hyaline cloud outside the 1st transverse cubital nervure at its junction with the cubitus and there is a smaller, clearer rounder hyaline spot in the 2nd discoidal cellule at the recurrent nervure; the basal nervures and the basal third of the stigma are rufo-testaceous, the rest of the stigma and the parastigma black; the 2nd cubital cellule is 3 times longer than it is wide at the apex; the 1st cubital cellule is lighter coloured than the 2nd, with a darker fuscous triangular cloud at the base in front. The hinder wings are of a paler yellowish hyaline colour to shortly beyond the apex of the basal fourth of the stigma; the fuscous apical cloud is obliquely widened from the top to the bottom. Abdomen longish oval, clearly longer than the head and thorax united and as wide as the latter; the basal 5 segments closely reticulated-punctured, the 2nd more strongly than the others; sutu-riform articulation wide, crenulated and with a roundly curved outer branch; there are weaker, similar furrows on the base of the 4th and 5th segments, which have also apical furrows. ♂.

Length 7 mm.

Kaluwala, near Dehra Dun, 3rd December.

On Sal leaf.

Antennæ slightly longer than the body, about 57-jointed, densely covered with white pile. Temples roundly narrowed, the occiput not quite transverse. Face smooth, broadly raised in the middle, pale yellow.

A longish narrow insect.

Ectadiophatnus, gen. nov.

Eyes bare. Antennæ 18-jointed, the basal joints of the flagellum and the apical 2 longer than wide, the others slightly wider than long. Clypeus clearly separated from the face. Stigma large, the radius issuing from its centre and extending to the apex of the wing, there being thus a closed radial cellule, cubitus extending only shortly beyond the 1st transverse cubital nervure; there is no 2nd transverse cubital nervure; the transverse median nervure post-furcal. Parapsidal furrows distinct, reaching from the base to the apex where they unite; they are crenulated. There is no pleural furrow, nor is the metanotum areolated. Abdomen compressed and widened from above to the ventral

surface; the hypopygium short, bluntly cultriform; the ovipositor as long as the thorax and abdomen united. The hind spurs short, the longer not one quarter of the length of the metatarsus.

The head is large, cubital, with the temples well developed, longer than the top of the eyes; the occiput is not transverse. Ocelli in a wide triangle, the hinder separated from each other by a slightly greater distance than they are from the eyes, which are separated from the mandibles by one-third of their length. There are 2 keels down the middle of metanotum.

This genus has not quite the appearance of the *Microgasterinæ*, the head being too cubital, through the well-developed temples. Characteristic are the closed radial cellule and the well-developed parapsidal furrows; the antennæ, too, are shorter and stouter—more moniliform—than they are in, *e.g.*, *Apanteles.*

Ectadiophatnus tachardiæ, sp. nov.

Black, smooth, shining, the legs rufo-testaceous, the hind femora in the middle and the hind tibiæ and tarsi infuscated; palpi white; the costa, parastigma and stigma fuscous, sparse, the nervures white. Pubescence short, sparse, white on the head and thorax, the abdomen bare, as long as the thorax; its 1st segment is longer than it is wide at the apex; its sides depressed; the 2nd is almost as long as it. ♀.

Length 2 mm., ovipositor 1·75 mm.

Bred from Lac, December 14.

The antennæ are not much longer than the head and thorax united and are covered by a microscopic pile; the scape is twice longer than wide and is as long as the 1st joint of the flagellum. The sheaths of the ovipositor are thin and are not thickened towards the apex.

Microgasterinæ.

Apanteles tachardiæ, sp. nov.

Black, the palpi and spurs white, the apex of the anterior femora, the anterior tibiæ and tarsi, the middle tibiæ to shortly beyond the middle, their tarsi and the hinder tibiæ and tarsi testaceous, the hinder darker in tint than the others; metanotum opaque, strongly aciculated, a longish oval shining depression in the centre, the sides margined by

a keel. Front and vertex finely, closely punctured, the meson'tum more opaque, more strongly punctured; the lower part of the mesopleuræ and the metapleuræ smooth, shining, bare, the rest of the pleuræ pilose, aciculated. Abdomen shorter than the thorax, the sheath of the ovipositor three-fourths of its length; the basal segment a little longer than it is wide at the apex, opaque and aciculated to near the apex, where there is a square shining space in the centre; the 2nd segment is wider than long; there is a curved transverse furrow near its base; the segments are fringed with white hair; the ventral are entirely black. Wings clear hyaline, the costa, parastigma and front of stigma fuscous, the rest and the nervures pallid white; the basal abscissa of the cubitus is thinner than the other nervures; the nervures bounding the apex of the 1st cubital cellule form an almost continuous curve; there is a short, but distinct stump of the cubitus. ♀.

Length 2 mm.

Bred out of Lac. 24th November.

PART II.

On some new and other species of non-parasitic Hymenoptera in the Collections of the Zoological Branch of the Forest Research Institute, Dehra Dun.

By P. CAMERON.

Introduction.

IN this paper I have enumerated and described the specimens contained in a collection of non-parasitic Hymenoptera sent to me by Dr. A. D. Imms, Forest Zoologist.

It includes a description of a new species of Saw-fly and an enumeration of the Aculeate Hymenoptera in the collection with description of the species which seem to be undescribed. The Saw-fly belongs to a genus, some species of which have proved very destructive to pine trees. I have also added descriptions of three new species from Simla and one Masuri (Mussoorree?) from my own collection. These are indicated by an asterisk.

Tenthredinidæ.

Lophyrus indicus, sp. nov.

Black, densely covered with short pale pubescence, the abdomen less densely so than the thorax; the labrum, palpi, apex of femora, that of the interior broadly, the tabiæ and tarsi pallid testaceous; wings hyaline, the stigma and nervures black, the former streaked with black at the base, the black with a transverse, longish triangular white spot at the base. Head and thorax closely, rather strongly punctured, the pleuræ more strongly rugosely so than the mesonotum; the face, clypeus, labrum and a line, dilated at the base, down the centre of the basal half of the scutellum; there is also a broad triangular smooth space at the base of the scutellum; the furrow bordering the base of the scutellum smooth and shining. Cenchri narrow, curved, rounded behind.

♂ Length 4 mm.

Dehra Dun. September, (*Forest Zoologist's Collector*).

Antennal rami fringed with white hair. Apex of clypens transverse, the sides rounded. Mandibles piceous, black at base and apex. There is a roundly curved shallow furrow behind the ocelli, making the centre of the vertex semicircular. There is a shallow furrow down the middle the central lobe of mesonotum. Metanotum more coarsely punctured than the scutellum, the basal segment of abdomen more finely and closely so. Transverse median nervure received shortly beyond the middle, the posterior third of 1st transverse cubital nervure faint, the basal abscissa of radius broadly roundly curved; the 2nd recurrent nervure is received shortly beyond the apex of the basal third of the cellule

ACULEATA.

Mutillidæ.

Mutilla sex-maculata, Swed.

Bingham, *Fauna of Brit. India, Hym.* i, 25. ♀.

Dehra Dun. July.

For remarks of this species and its ♂, *cf.* Cameron, *Ann. Mag. Nat. Hist.* IV (7), 60.

Pompilidæ.

Salius flavus, F.

Bingham, *l.c.*,

Gorakpur.

Salius (Prionemis) dehraensis, sp. nov.

Black, the basal 2 abdominal segments all round and a curved band on the base of the 3rd above, ferruginous, wings hyaline, a fuscous cloud filling the radial cellule, the 2nd cubital, except for a triangular hyaline cloud at the base below, the 3rd entirely, these clouds extending into the discoidal cellule as a somewhat semicircular, fainter one on its apical half; 2nd abscissa of radius more than double the length of the 3rd, 1st recurrent nervure received near the base of the basal third, the 2nd nearer the middle. Claws unidentate, the base roundly dilated. Eyes slightly converging above, the hinder ocelli separated from each other

by a slightly less distance than they are from the eyes. Apex of clypeus broadly rounded. Third antennal joint about one quarter longer than the 4th. Metanotum transversely striated, more weakly at the base than elsewhere. Apex of pronotum bluntly, roundly angled in the middle. Long spur of hind tibiæ slightly more than one-third of the length of metatarsus and as long as the 2nd joint. ♂.

Length 8 mm.

Dehra Dun, July.

Metanotum gradually roundly sloped from the base to the apex, the metapleuræ opaque, pronotum large, rounded in front probably in fresh examples the head and thorax are densely covered with white pubescence, in the specimen examined it is dense on the mesopleuræ and coxæ.

Comes, in Bingham's work, nearest to *S. electus* Cam.

Pseudagenia tincta, Sm.

= *Mutabilis* Sm.—Bingham, *Fauna of Brit. India, i,* 116.
Dehra Dun. October.

Sphegidæ.

Sceliphron tibiale, Cam.

Ann. Mag. Nat. Hist., 1899, IV (7) 54.

Two damaged specimens taken at Rundali, Dehra Dun, in June are probably referable to this species of which *S. lineatipes* Cam. is perhaps a variety. The tibiæ in the Dehra Dun examples are only lined with black in front, not entirely black as in the type. *S. tibiale* is a variable species as regards the markings, a less rare form has 2 yellow marks in the centre of the metanotum. Its nearest ally known to me is the New Guinea species *S. Bruinjnii*, Maid. *S. lorentzi* Cam. being also related to it. *S. Bruinjnii* may be known from it by the post-petiole, and all the following abdominal segments being ferruginous, with the base of the 3rd to 6th lined with black, the apex of its clypeus, too, is broadly rounded, not bilobate.

Liris nitidus, sp. nov.

Black, smooth, shining, the metanotum opaque, the basal part with a narrow furrow having a keel down its centre, it is slightly shorter than

the rest of the thorax, its apex is rounded broadly above, the sides of the apical slope irregularly transversely striated, more strongly above than below. The head, base of mandibles and pronotum densely covered with golden pubescence, probably in fresh examples the whole thorax is so. Pygidium closely striated, the sides and apex covered with golden pile ; no doubt in fresh examples the whole surface has a golden pile There are indications of a golden or silvery pile on the apices of the abdominal segments. Wings black, tinged with violaceous, the stigma and nervures black, basal abscissa of radius as long as the following 2 united, the 2nd one-fourth of the length of the 3rd ; the 2nd recurrent nervure received shortly beyond the apex of the basal third of the cellule. The space between the recurrent nervures is as wide as the 2nd abscissa of the radius. Pubescence on metathorax white. ♀.

Length 18 mm.

Dehra Dun, December (*J. W. Judd*).

Comes near to *L. nigripennis*, Cam., which may be known from it by the almost hyaline cubital cellules, by the apex of metanotum being abruptly truncate and by the head and thorax being, "dull, opaque, very minutely punctured," not smooth shining and impunctate, as in *L. nitidus*.

Ampulex compressa, Fab.

Bingham, *Fauna of Brit. India*, i.

Garhi, Dehra Dun, July (*Forest Zoologist's Collector*).

Trypoxylon ornatipes, sp. nov.

Black, the 2nd abdominal segment, the 3rd, and the basal fourth of the 4th above and the basal third of the sides rufo-testaceous ; the anterior tarsi, basal 2 joints of the middle, the base of the 4 hinder tibiæ narrowly, the spurs and the apex of the trochanters more obscurely, whitish yellow, the fore tibiæ for the greater part pale testaceous, especially in front. Wings hyaline, the stigma and nervures black. Mandibles rufo-testaceous. A shallow furrow down the centre of the upper half of the front which is roundly bilobate, below it, on the lower half, is a distinct keel. Metanotal area with the central depression longish oval, narrower at the apex than at the base, irregularly transversely striated, the lateral bounding furrows with the striæ stronger and more

regular. Pubescence on the lower part of eye incision outer orbits, face and clypeus dense and silvery, on the pleuræ it is longer and sparser, more like hair than pubescence. Abdominal petiole nearly as long as the following 3 segments united, the apex not forming a distinct node, gradually, weakly widened towards the apex. Tegulæ piceous. Front and vertex closely, minutely punctured, the mesonotum shining, almost impunctate. ♂

Length 9 mm.

Dehra Dun. July, at light.

The furrow on apical slope of the metanotum is wide, with obliquely sloped sides, slightly roundly narrowed towards the apex and with a keel in the centre. The apex of the wings is faintly clouded.

Comes near, of the Indian species, to *T. bicolor*, Sm.

DIPLOTERA.

Vespinæ.

Polistes stigma, F.

Dehra Dun, 25th March. The example is of the race *stigma*, but darker coloured than usual for that form.

Icaria annulipes, sp. nov.

Rufous, or rufo-testaceous; the sides of the clypeus broadly, the apex more narrowly, the rufous central part widened towards the apex, a broad line on the inner orbits from the incision to the antennæ, the antennal keel for the greater part, a narrow line across the base and a less distinct one on the sides, a line on the base of scutellum, broader one on the base and sides of post-scutellum, 2 large lines on the metanotum, a line on the base and apex of mesopleuræ, one on the sternum extending on to the pleuræ, a mark on base of metapleuræ, gradually widened below, 2 oval marks on the apex of post petiole, a transverse oval one, near the centre of the 2nd segment, on the outer part, a broad line, of equal width, on the base of the 2nd, filling the outer two-thirds, a shorter one on the sides of the 3rd, a squarish mark on the sides of the 6th; 2 oval marks on the centre of the 2nd ventral, lines on the base of the 3rd or 5th, dilated laterally, and an oval mark on the sides of the

6th, pallid yellow. Legs coloured like the body, the hind tarsi darker in tint, the apex of femora and a line or spot near the apex of the tibiæ pallid yellow. Wings hyaline, the apex of the costal and the greater part of the radial cellule smoky, the stigma and nervures black.

The ♂ has the yellow markings more widely extended, the face, clypeus and mandibles are entirely yellow, the 2nd ventral segment has one large mark, roundly incised at the base, and the femora and tibiæ are yellow below.

Length ♀ 15, ♂ 13 mm.

Dehra Dun, March—July (*Forest Zoologist's Collector*).

Abdominal petiole longish, in ♀ as long as the 2nd segment, the apical half nodose, pyriform, twice longer than wide. There is a shallow furrow down the middle of the scutellum. Metanotal furrow wide and shallow, a weak keel down the middle. The eyes below in the ♀ are separated by the length of the antennal scape and pedicle united, in the ♂ by the length of the 3rd joint of the flagellum, the eyes strongly converging below; the clypeus in the ♂ is almost twice longer than wide, widened gradually towards the apex, which is broadly rounded. The 7th to 9th joints of the flagellum are broadly, but not much dilated below, the last is about one-fourth longer than the penultimate, is longish ovate, and simple, not curved, hollowed below and dilated as in *I. variegata.*

Comes near to *I. fuscipennis.* Cam. from the Khasias, which is dark chocolate in colour, and has the yellow markings much larger all over the body and legs and, more particularly, on the legs and pleuræ. The clypeus in the ♀ of *fuscipennis* is slightly longer as compared with the width and, more particularly, is bluntly rounded at the apex, not ending in a sharp point as in *annulipes.*

Odynerinæ.

Ancistrocerus sikhimensis, Bing.

Fauna of Brit. India, Hymen., i, 363.

Jaunsar.

Odynerus ornatus, Smith.

Bingham, *l.c.*, 364.

Dehra Dun, September (Butterwick).

Bingham, *l.c.*, refers this species to *Odynerus* (*sensu str.*,) but Smith himself [*Ann. Mag. Nat. Hist.*, (2) IX, (1852), p. 49] calls it an *Ancis-*

trocerus. Bingham does not appear to have been actually acquainted with the species, for he, *l.c.*, only copies Smith's description. I have a ♂ from Bombay, which agrees with Smith's description of *ornatus*, except that it is not an *Ancistrocerus.* I give here a description of both sexes of the Dehra species.

♀ Ferruginous, a broad oblique line over each antenna, about one-half longer than wide and united below by a narrower black line, a large spot covering the ocelli, more developed below than above them, narrowed gradually from the bottom to the top, the bottom transverse, except for a shallow incision in the middle, the occiput except above, more than the lower half of the occiput, a large mark on the basal half of the mesonotum, dilated laterally at the base, the apex gradually slightly narrowed to a rounded point, a squarish mark on either side of the apex, the edges of the scutellum and post-scutellum, the base of the propleuræ, the base of the mesopleuræ, the mark becoming widened below, squarish mark on the upper apical half, the base of the 2nd, 3rd and 4th abdominal segments, their apices more narrowly, a mark narrowed towards the apex, on the 2nd ventral segment and a line bordering the apex of post-scutellum and going down the centre of metanotum, black. Legs coloured like the body, the base of 4 front femora and the hinder to near the apex, black. Wings yellowish hyaline, clear in tint behind, the radial cellule clouded. The puncturation on the head and thorax is strong and close, the post-scutellum more rugosely punctured than the scutellum, its apex above raised, crenulated, forming a segment of a circle. Sides of metanotum broadly rounded. First abdominal segment large, cup-shaped, the 2nd longer than it is wide at the apex.

The ♂ is similarly coloured except that the clypeus, mandibles, except at the edges, a triangular mark on the front, continued as a short line between the antennæ and a line on the lower part of the eye incision are bright lemon-yellow. The clypeum in the ♀ is longer than wide, closely distinctly punctured, its apex depressed, the sides forming shining reddish teeth; in the ♂ the clypeus is wider compared with the width less closely punctured and there is a rounded incision on the apex; the legs bear less black. No doubt the black markings vary in size and shape.

Rhynchium argentatum, F.

Bingham, *F. of B. India, Hymen.*, i, 358, 633.
Mussoorie.

Anthophila.

Ceratina Binghami, Cock.

Viridissima, Bing., *Fauna of Brit. India, Hymen*, i, 501.

Lachiwala, near Dehra Dun. May.

Megachile stirostoma, sp. nov.

Black, the pubescence, including the pollen brush, and bands on the base of the dorsal abdominal segments, white, the upper part of the ventral surface with black hairs. Wings hyaline, iridescent, the apex from end of the cubital cellules slightly smoky, the nervures black. ♀.

Length 14 mm.

Dehra Dun.

Head large, slightly wider than the thorax, closely punctured, a smooth narrow furrow running from the occiput to the ocelli, clypeus above forming a wide triangle depressed and punctured in the centre and bordered by flat shining broad keels; below this is a shallow transverse depression, followed by a larger deeper one, bordered below by 2 smooth wide transverse keels, of which the lower is the wider and is dilated slightly in the middle. Mandibles longish, covered with longish, interlacing punctures; the lower apical part furrowed, there are 2 broad, rounded teeth, the inner thinner and widely separated from the apical. Puncturation on mesonotum close, and running more or less into transverse striæ; there is a narrow, smooth irregular shining line down the middle apex of scutellum and post-scutellum fringed with longish black hair. Metanotal area opaque, smooth, clearly separated, a shallow furrow down the middle; the rest of the metanotum is not so strongly punctured as the scutellum. Apex of basal abdominal segment closely, regularly punctured, the 2nd and 5th with the apical half more or less irregularly punctured, the punctures becoming gradually weaker and sparser, the last much more closely, finely and regularly punctured and covered with short, stiff black hair; the apical ventral segments thickly covered with longer black hair. The base of the 2nd and 3rd segments distinctly, the 4th slightly depressed. The base of metatarsus is not much more than half the width of the apex of hind tibiæ. Front

between the antennæ broad, flat on the same level as the vertex, not projecting.

Belongs to Bingham's Section F (*Fauna of Brit. India,* I, 472) and runs to *M. cephalotes.* Bingham has omitted in his description the colouration of the wings; Smith, *Cat.* I, 179, calls them "subfuscous, hyaline towards their base."

Cœlioxys sulcispina, sp. nov.

Black, the face, lower part of front broadly at the eyes, the lower three-fourths of the outer orbits, a small tuft in the middle of the mesonotum at the base, the part at the base of tegulæ, a small patch behind them, 2 transverse tufts on the base of scutellum, the mesopleuræ and mesosternum, the upper and lower part of metapleuræ densely, the central sparsely, patches, narrowed inwardly, on the sides of the abdominal segments and continuous lines on the ventral of snow white pubescence; wings to the 2nd cubital cellule in front, to the 2nd recurrent nervure, hyaline, the rest fuscous, tinged with violaceous, the 1st cubital cellule and the greater part of the space between the recurrent nervures lighter in tint than the apical part, the nervures black. Apex of scutellum broadly rounded, the centre with a small rounded incision, the sides project into stout teeth, broad at the base, narrowed towards the apex, which is rounded, the sides are margined with a stout keel, the outer keel straight and commencing at the mesonotum, the inner shorter and rounded. Metanotal area semicircular, opaque, its base with a stout keel down the basal half in the centre, the base with a short striated border. Apical abdominal segment with 8 teeth, 2 short basal, 4 upper apical, of which the central 2 are stouter and broader than the outer and having a small flat shining keel in the centre and 2 longer sharper pointed ones below. Head, pro- and mesonotum with scutellum strongly punctured; the 1st abdominal segment and the 4th and following more finely and closely so, the 2nd smooth, the base with a row of scattered punctures followed by a curved line of punctures in a shallow furrow, on the apex is a regular row of furrows, with some scattered ones before it in a curve, the 3rd is irregularly punctured, almost smooth near the base and apex, its apex and that of the 4th with a regular row of small punctures in a shallow furrow. Ventral surface with the puncturation closer, finer and more regular than they are above. Legs

densely covered with snow-white pubescence, that on the under side of the tarsi tinged with rufous. ♂.

Length 9-10 mm.

Sabhawalla, near Dehra Dun. June.

Looked at laterally the scutellar teeth are broad and have the apex bluntly rounded. The tegulæ are piceous on the outer margin. The puncturation on the basal abdominal segment is finer, but not any closer than it is on the apical 2 ; on the 4th it is sparser than it is on the 5th. Mandibles coarsely punctured at the base, the lower part furrowed, the upper basal half with a longish oval furrow.

Coelioxys fulvitarsis, sp. nov.*

Black, the sides of the clypeus above, the face, lower three-fourths of outer orbits, pronotum, pleuræ, metanotum, the base and sides of the 1st abdominal segment, narrow lines, triangularly dilated laterally, on the 2nd to 5th, and wider lines, widely interrupted in the middle, on the ventral basal 5th, of white pubescence; the hair on the face and clypeus tinged with fulvous ; the pubescence on the legs white, on the underside of the tarsi bright rufo-fulvous. Wings fuscous-violaceus, the base to the transverse basal nervure paler in tint, but still tinged with violaceous, the nervures and stigma black. Face broadly rounded in the centre, smooth, clypeus with a distinct keel down the centre. Apex of scutellum broadly rounded, roughly margined, the teeth broad, about one-half longer than wide, slightly narrowed towards the apex, which is bluntly rounded. The ventral apical segment projects distinctly over the dorsal; which has the basal half closely punctured, more strongly on the apex than on the base, and with a smooth line down the centre, the apical half has a distinct keel down the centre, its base is depressed on either side of the keel; the apex laterally is margined; the surface is rugosely punctured, more coarsely and less closely on the base than on the apex; the ventral surface is closely, somewhat strongly striated, the striæ intertwining. ♀.

Length 14 mm.

Masuri (Mussoorree ?).

The puncturation on the clypeus is coarse, irregular, closer above than below, where the punctures run into reticulations ; on the face and front they are smaller, deep, round and clearly separated. Vertex strongly,

irregularly punctured. Mesonotum closely, rugosely punctured, more strongly at the apex than at the base; the scutellum as strongly punctured as the apex of the mesonotum, but closer and with the punctures running into reticulations. Metanotum closely, finely rugose, opaque. Abdomen closely, distinctly punctured, more sparsely towards the apex than at the apex, the puncturation less close in the centre of the apical half of the segments.

Comes near to *C. sex-maculata*, Cam.

Coelioxys tenuilineata, sp. nov.*

Black, shining, the face, clypeus, front, outer orbits, the base and apex of mesopleuræ densely, the centre sparsely, narrow bunds, not much dilated laterally, on the apices of the basal 5 abdominal segments, broader ones on the ventral and the legs covered with snow-white pubescence. Wings almost hyaline to the base of the stigma, fuscous violaceous beyond; the nervures black. Scutellum strongly, sparsely punctured, the punctures closer on the sides, in the centre sparser on the apex than on the base, the lateral spines about twice longer than wide, of almost equal width throughout, rounded at the apex, convex above; the apex laterally bluntly rounded. Apical half of last abdominal segment gradually narrowed to a point, closely punctured, a smooth keel down the centre, the apex of ventral long, acutely pointed, aciculated, the base finely punctured; it projects largely beyond the dorsal segment. Apex of clypeus bluntly rounded. Abdominal segments finely, closely punctured at the base and apex of the basal 5 segments; the basal half of the 6th smooth. ♀.

Length 10-11 mm.

Simla.

In certain lights the back of the abdomen is tinted with violaceous. Looked at from the mesonotum the apex of the scutellum is seen to be slightly reflexed and has an incision in the centre. The head and thorax have the usual puncturation.

Coelioxys fuscipes, sp. nov.*

Black, the legs brownish fuscous, darker behind than in front; the face, clypeus, front, outer orbits, a spot before and behind the tegulæ,

2 small transverse spots on the scutellum, the greater part of the pleuræ and sterna, narrow bands on the apices of the dorsal and wider ones, mostly interrupted in the middle, on the ventral abdominal segments, of snow white pubescence, the legs clothed with similar pubescence. Scutellum more strongly and less closely punctured than the mesonotum, the punctures sparser on the centre of the apical half; the apical margin broadly rounded, slightly raised and with a rounded incision in the centre; the teeth short, not quite twice longer than wide, a small and a large fovea on the top. Wings hyaline to the 1st recurrent and 1st transverse cubital nervures, the 2nd recurrent almost interstitial. Basal 4 abdominal segments closely punctured, the punctures becoming weaker towards the apex; there is a smooth transverse line on the sides of the segments near the apex; the 5th segment weakly, closely punctured, the basal half of the 6th very weakly, the apical more distinctly, closely punctured; there is a fine smooth keel down the centre of the basal half; basal third of apical ventral segment smooth, the middle closely punctured, the apical third smooth; it projects, but not much, over the dorsal segment and becomes gradually narrowed towards the apex. ♀.

Length 12 mm.

Simla.

Apex of clypeus bluntly rounded; the clypeus large, longer than the face, roundly convex. The centre of the apex of the scutellum is almost bilobate, being separated from the sides and having a central incision; the apex of the last abdominal segment is not acute, but rather bluntly rounded. There is an indication of a keel on the front. There are no transverse furrows on the abdominal dorsal segments.

Coelioxys ruficaudis, sp. nov.*

Black, the apical abdominal segment from near the base red; the legs brownish red; mandibles rufous, the teeth black; flagellum rufo-fuscous below; wings hyaline, the stigma and nervures black. Apex of scutellum rough, broadly rounded, the lateral teeth large, bluntly rounded at the apex, the sides broadly roundly curved, the centre with a large deep hollow, widened and deepened at the base of the inner curve. Pubescence dense and silvery, almost covering entirely the outer orbits, pleuræ, sternum and legs; 2 small spots, longer than wide, on the base of mesonotum, one at the sides, near the base and apex of the tegulæ,

2 small, narrower, transverse ones on the base of scutellum, and bands, widened outwardly, on the apices of the abdominal segments above and narrower ones below of silvery pubescence. Ventral plate of apical abdominal segment broadly triangular, slightly longer than it is wide at the base. Front without a median furrow. Scutellum short, rounded behind. A wide transverse furrow on the apex of the 2nd abdominal segment. ♀.

Length 6 mm.

Simla.

Clypeus finely, the front and vertex coarsely rugosely punctured, the former not much raised, its apex transverse, narrowly rufous. Thorax coarsely rugosely punctured. Apical half of last dorsal segment of abdomen depressed laterally, projecting beyond the central basal part, which becomes, at the apex, gradually roundly narrowed to a fine point; this apical part is more coarsely punctured than the rest. The sides of the last ventral segment are broadly raised on the apical half, the centre appearing as a consequence depressed.

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PROSOPIS JULIFLORA, DC.

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INDIAN FOREST RECORDS.

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Useful Exotics in Indian Forests

No. 1. Prosopis juliflora, *DC.* (*var.* glandulosa, *Sarg.*)

By R. S. HOLE, F.C.H., F.L.S., F.E.S.,
Botanist, Forest Research Institute, Dehra Dun.

INTRODUCTION.

IN the light of the economic results obtained from the gradual extension of the area producing such crops as food-grains, sugar, cotton, tea, coffee and rubber, by the agriculturist and the planter, it is unnecessary to emphasise the importance of cultivating exotics. Whether caused by this success which has been realised in particular cases and under particular circumstances, whether on account of a prophet being without honour only in his own country, or whether it be induced by the feeling that great economic results may be realised with very little trouble or exertion, *viz.*, by the royal and easy road of obtaining and putting in the ground the seed of a particular plant, it is certain that a tendency to exaggerate the importance of exotics and to overlook the value of indigenous plants frequently exists and this is a point which may be profitably emphasised, especially with reference to forestry. Perhaps no better example of the above tendency can be quoted than that mentioned by Sir George Watt in connection with the Tea industry. In the first days of tea-planting in India the indigenous

Frequent tendency to exaggerate importance of exotics and to neglect indigenous plants.

Assam forms of the tea plant were regarded as "degraded" and consequently the Chinese small-leaved plant was introduced at considerable cost with the result that "for the past 30 or 40 years the planters have deplored the day when the so-called Chinese tea plant was brought to India. At present no planter would for a moment dream of planting China tea, few would even grow the hybrid, while the majority would cultivate but one only of the several so-called indigenous stocks."[1]

Disadvantages of exotics.

2. It is well to remember that several serious drawbacks usually attend the cultivation of exotics. In the first place the reports circulated regarding the dimensions attained and products yielded by plants are frequently untrustworthy and it is as a rule impossible to personally verify these satisfactorily by local inquiries. From 1862—1889 statements were frequently circulated that the gum trees (*Eucalyptus*) of Australia attained a height of 400—500 feet and even more. Careful measurements made in Australia about 1888, however, showed that not a single tree could be found which exceeded 326 feet 1 inch. It is clear that estimates of timber yield, based on data of this kind, and on which calculations regarding the probable profit to be obtained from the introduction of these trees necessarily depend, would have been worthless. It must also be remembered that estimates of value are merely comparative. *Prosopis spicigera* is undoubtedly a very valuable species in desert tracts where practically no other tree will grow, but it would obviously be absurd to introduce it into forests where many species already exist which are superior in all respects. Similarly statements regarding the value of exotics must be carefully considered with reference to the value of those indigenous species which it is proposed to replace.

Reports on exotics often untrustworthy.

Deterioration.

3. We have also to reckon with the widely known and most important fact that, although many plants thrive and can be cultivated in various countries and climates, it by no means follows that the growth and quality of the commercial products, for the sake of which they are cultivated, will remain the same and will not deteriorate under such different conditions. Darwin mentions the following examples of such deterioration : "The Hemlock is said not to yield conicine in Scotland. The root of the *Aconitum napellus* becomes innocuous in frigid climates * * As the *Pistacia lentiscus* grows abun-

[1] *Commercial Products of India,* 1908, pp. 213, 216.

dantly in the South of France, the climate must suit it, but it yields no mastic. The *Laurus sassafras* in Europe loses the odour proper to it in North America. * * The wood of the American Locust-tree (*Robinia*) when grown in England is nearly worthless, as is that of the Oak-tree when grown at the Cape of Good Hope. Hemp and flax, as I hear from Dr. Falconer, flourish and yield plenty of seed on the plains of India, but their fibres are brittle and useless. Hemp, on the other hand, fails to produce in England that resinous matter which is so largely used in India as an intoxicating drug."[1] This fact is particularly important for the forester who has to wait many years before he can ascertain the quality of the timber produced by any particular species.

Deterioration due to two factors.

It is probable that this so-called deterioration depends mainly on two factors, *viz.*,—

Inferior seed.

(1) That inferior seed is sown. In one and the same species, especially if it be a widely distributed and variable one, numerous distinct forms may be included which cannot conveniently be distinguished in descriptive botany without confusing the student of field botany and the practical forester, owing to the number of intermediates which occur between them. These forms, however, if intercrossing is prevented, are frequently capable of transmitting their characters truly to their offspring. Such forms also differ widely in their economic importance, and whereas one may yield a timber of importance, another is merely a straggling worthless shrub. As such forms, however, are not differentiated botanically, the seed of the worthless forms is just as likely to be gathered and distributed as is that of the more valuable types. The species *Catalpa speciosa*, Engelm., for instance, which of recent years has been widely sown in India, is said to include a form which gives only crooked and worthless trees and from the results obtained in at least one Indian Division where the seedlings of this tree have survived it appears that they belong to the worthless form. Again, a consignment of seed of *Prosopis juliflora*, DC., was sent to India from the Botanical Department of Jamaica about 1884 with the following description " an admirable tree (often attaining a height

[1] *Animals and Plants under Domestication*, 2nd Ed., 1893, II, p. 264.

of 40 to 60 feet) to grow in dry gravelly soil, and in situations where rain does not fall for months together. It is fast growing : the timber is excessively hard and of a remarkably durable character. It is used for making knees of boats and all work requiring strength and tenacity."[1] The results of cultivating this species for 25 years in India have consisted in the production of "a large straggling bush with bramble-like shoots 10 to 15 feet long and 3—4 inches in diameter at the lower ends." [2] Bentham described this species in 1876 as "a tall shrub or tree, 15—20 feet high, rarely higher," and notes that it is very variable as regards height and other characters.[3] Here again it is possible that we have obtained a comparatively valueless form of the species. The only way of avoiding this difficulty is to insure a supply of pure seed of the best forms of each particular species. The great importance of collecting seed for sowing only from the best and most vigorous individuals has, of course, long been recognised in forestry, but it is obviously difficult to insure this in the case of exotics where we are usually obliged to depend on unknown correspondents.[4]

Unsuitable environment.

(2) That the plants are exposed to an unsuitable environment. When mixed seed of various forms of one and the same species is received this fact may result in the survival of only worthless types, the conditions not being such as to allow of the healthy development of the more valuable forms. On the other hand, when pure seed is obtained of the best types, the difference in the nature

[1] *Indian Forester*, X, 1884, p. 293.

[2] *Bull. No. 21, Dept. of Land Records and Agri., U. P., 1906, p. 31.*

[3] *Flora Brasiliensis* by C. F. P. DeMartius, Vol. XV, Part II, p. 289.

[4] It is believed, however, that we might well pay more attention to this point in connection with the propagation of our own indigenous species. Thus, in experimental cultures which have been carried on at Dehra Dun during the last few years, it has been noticed in the case of several species that individual seedlings grown under similar conditions differ from each other as regards vigour and rapidity of growth to an altogether remarkable extent and also, for instance, that teak seed obtained from Burma has invariably given far more vigorous plants than teak seed obtained from the Central Provinces.

and intensity of the factors of the environment may so change the characters of the plants and the quality of their commercial products as to render them of comparatively little value. Thus, in one locality, fast grown timber with a large proportion of "spring-wood" may be produced, while, in another locality, slow-growing timber with a large proportion of dense "autumn-wood" will be developed which is of higher value for many purposes. The only way of avoiding this difficulty is to see that, so far as possible, each plant is grown under conditions similar to those to which it is accustomed in its native country. Although the omission to ascertain these conditions frequently leads, not only to deterioration in value, but even more frequently to the death of the plants, the importance of this point is frequently overlooked and waste of time and money necessarily results.

Thus *Eucalyptus Globulus,* Labill., is well known to be one of the least hardy of the more valuable species of the genus and yet it is probably still one of the most frequently planted and often in localities totally unsuited to it. As a general rule it may be said that, other things equal, plants possessing xerophilous characters and which develop well in a strongly xerophytic habitat are most likely to withstand both frost and drought. Regarding the natural habitat of *E. Globulus,* Von Mueller wrote as follows in 1880: "in valleys as well as on ridges and mountain-slopes, chiefly in humid regions * * not ascending to alpine elevations."[1] This obviously does not sound like a xerophytic habitat and should have been a sufficient warning to prevent its introduction into such localities. Again the same author *l.c.* notes: "it (*i.e.,* *Eucalyptus alpina*) will endure such severe frosts, as at once would prove detrimental to *E. Globulus,*" and "*E. Globulus* among tall congeners cannot rival *E. pauciflora, E. amygdalina* and *E. Gunnii* in hardiness." Experiments with *E. Globulus* in the Simla Division of the Punjab (1903—07) showed that this species was "particularly susceptible to the effect of frost and drought," but even now proposals are sometimes made to introduce this species into the extremely xerophytic forest-locked grasslands of our plain-forests. The policy frequently followed with reference to the cultivation of

[1] *Eucalyptographia,* Decade VI.

exotics appears to consist in haphazard experiments with species of more or less economic importance, carried on with little or no knowledge of the conditions likely to be most suitable for those species and in localities the essential characters of which are very imperfectly known. A more rational policy, and one which is essential if waste of money and time is to be avoided, would consist in (1) a careful preliminary study of the localities we desire to afforest with the object of determining their power of supporting particular types of vegetation, (2) in selecting those exotics for trial which are known to thrive in similar habitats, and which are likely to give a better economic return than those indigenous species, capable of growing in the same localities. In considering the value of exotics, the fact is frequently overlooked that the most valuable species, *e.g.*, those of the well-known genus *Eucalyptus*, frequently only thrive in the more favourable hygrophytic and mesophytic habitats, and that those characteristic of xerophytic localities are often of no commercial value. Thus *Eucalyptus virgata*, Sieb., var. *stricta*, Maiden, is "a dwarf gum, very abundant on the higher parts of the Blue Mountains * * where it often forms an almost impenetrable scrub. On the bleakest parts of our ranges, up to between 4,000 and 5,000 feet, this dwarf gum luxuriates * * height from 6—15 feet * * too small for timber." [1] Again, Von Mueller writing on *Eucalyptus amygdalina*, Labill. (including the form *E. regnans* F. V. M.), which is the giant of the genus, says "in the irrigated ravines of cooler ranges the tree attains the most towering height, * * in more open and in merely ridgy country *E. amygdalina* remains much lower in stature, even often a comparatively dwarf tree." [2]

Great liability to disease and injuries.

4. Next to deterioration comes the no less important fact that exotics are very liable to suffer severely from diseases and injuries to which indigenous plants are comparatively immune. This, after all, is only what we should naturally expect, seeing that indigenous plants, by the mere fact of their survival in a prolonged struggle for existence, have proved their ability to withstand the injurious influences of their environment. This point is strikingly illustrated by the way in which rabbits and deer often especially select exotics for their attacks in European plantations. In India forest-exotics have again and again been found to suffer more severely than indigenous

[1] *Forest Flora of New South Wales* by J. H. Maiden, III (1908), p. 86.

[2] *l. c.* Decade V, 1880.

species from the attacks of insects, deer, pigs, monkeys and hares. The European larch (*Larix europæa*), also, is known to suffer to a slight extent from the canker disease induced by the fungus *Peziza Willkommii* when growing in its native home in the Alps at an elevation of 3,000 to 6,000 feet. This dreaded disease, however, only assumed an epidemic character when the tree was introduced as an exotic into the valleys and lowlands of Europe. * * In Cape Colony, in Africa, under the special circumstances of only a few indigenous species being of commercial value, their growth being slow and reproduction poor, exotic species have been largely introduced. One of these "*Pinus Pinea* (stone pine) was introduced by the early settlers, but some thirty years ago it was attacked by a fungoid disease which has almost exterminated the species;" and Sir William Schlich remarks: "the only disquieting point is that some of the exotic species introduced on a large scale may some day share the fate of the stone pine and be destroyed by disease; hence somewhat more attention might have been paid to the indigenous species."[1]

One of the most practical preventive measures against the injuries of insects and fungi is to adopt mixed crops, but exotics are frequently planted pure, partly no doubt because information is not readily available as to what mixture is likely to suit them. It may be argued that, with the progress of knowledge in modern times, it should be possible to adopt measures which shall prevent, or at all events greatly diminish, such injuries. In the first place, however, the only effective remedial measures are usually very costly and for this reason alone methods which are possible for the arboriculturist, planter and agriculturist are not practicable in forestry where the areas to be dealt with are large and the margin of profit usually small. The practical destruction of the coffee industry in Ceylon by the fungus *Hemileia vastatrix* in comparatively recent years, moreover, indicates how futile such measures may be in the case of a really severe fungal epidemic. In the case of agriculture the production of new, disease-resisting varieties by plant-breeding appears to be the line of work which is at present regarded as the most likely to give the best results in preventing disease, but measures such as these are not at present possible in practical forestry except, perhaps, in so far as the collection of seed from the most vigorous and healthy individuals may lead to the propagation of disease-resisting strains. In forestry, we

[1] Manual of Forestry, Vol. 1, 1906, pp. 139, 140.

must as a rule accept our species as they exist in nature and the best procedure appears to consist in elaborating our treatment of them in such a way that each species is wounded as little as practicable and is provided as far as possible with the conditions of soil, moisture, climate and light, which suit it best in nature. In this way it is possible to keep up the general health of our plants and to avoid many diseases which are primarily due to inferior vigour. Our chances of success in this respect, therefore, are obviously greater in the case of indigenous plants, with the needs of which we are more or less intimately acquainted, than in the case of exotics of which we know comparatively little.

Special difficulties with exotics in forestry.

5. Due regard being paid to the financial results of the operations, it becomes, as a rule, impossible in forestry to employ (except occasionally on a very limited scale) methods of cultivation which greatly assist the healthy development of plants and which are more or less generally employed by gardeners, agriculturists, arboriculturists and planters. Such methods, for instance, include the thorough working of the soil, the artificial supply of water at critical periods and effective protection from the competition of other plants. Successful growth in gardens and avenues, therefore, is no criterion of a tree's ability to constitute a profitable forest crop in the same locality. Time after time, in India, plants which have grown well in the nursery have entirely failed to hold their own in the forest.

Finally, it must be remembered that mistakes, in the way of introducing unsuitable species, cannot, as a rule, be so quickly, or so cheaply, rectified by the forester, who has to wait many years for the development of his plants and for the maturing of their products, as by the agriculturist or planter. In forestry, therefore, it behoves us to be particularly careful to avoid being dazzled by the brilliance of the exotic which only too frequently proves to be a mere *ignis fatuus*.

Exotic cultivation by Indian Forest Officers during recent years.

6. Some idea of the work now being done by Indian Forest Officers in the way of cultivating exotics will be obtained from a perusal of the list given below. This list gives details of the exotic species, the introduction of which has been attempted by Forest officers in the different provinces of India during the last few years. It has been compiled from information kindly supplied annually

to this office by Conservators since 1907. It has not been possible in every case to verify the specific names from the literature available at Dehra Dun and such names have then been entered as they were reported :—

MADRAS.

Acacia auriculæformis.
" *dealbata.* (Australia.)
" *melanoxylon.*
Acer Pseudo-Platanus. (Europe.)
5. *Æsculus Hippocastanum.* (European Horse Chestnut.)
Agave sp.
Albizzia fastigiata. (Africa.)
Anacardium occidentale. (Cashew of the W. Indies.)
Araucaria Cunninghamii. (Australia.)
10. *Aristolochia odoratissima.* (Jamaica.)
Cæsalpinia coriaria. (C. America, W. Indies.)
Callitris rhomboidea. (Australia.)
Calodendrum capensis. (S. Africa.)
Carapa guianensis. (Guiana, tropical Africa.)
15. *Carludovica jamaicensis.* (W. Indies.)
Catalpa speciosa. (N. America.)
Cedrela odorata. (S. America.)
Cinnamomum Camphora. (China, Japan.)
Cryptocarya (Natal.)
20. *Erythrina tomentosa.* (Abyssinia.)
Eucalyptus eugenioides.
" *Globulus.*
" *marginata.* (Australia.)
" *resinifera.*
25. " *rostrata.*
Fagus sylvatica. (Europe.)
Grevillea robusta. (Australia.)
Hæmatoxylon campechianum. (Logwood of tropical America.)
Harpephyllum caffrum. (S. Africa.)
30. *Hevea brasiliensis.* (Para Rubber of Brazil.)
Hymenæa Courbaril. (S. America.)
Jacaranda sp.
Juniperus barbadensis. (Bermuda I.)
Kickxia africana. (Tropical Africa.)
35. *Landolphia florida.*
Leucadendron argenteum. (S. Africa.)
Manihot Glaziovii. (Ceara Rubber of Brazil.)
Millettia caffra. (S. Africa.)
Mimusops globosa. (Tropical America.)

40. *Passiflora edulis.* (Brazil.)
Peltophorum Linnaei. (Jamaica.)
Phœnix dactylifera. (N. Africa, Arabia.)
Picea Parryana. } (N. America.)
" *sitchensis.* }
45. *Pinus attenuata.* } (California.)
" *Coulteri.* }
" *insignis.* }
" *Lambertiana.* }
" *ponderosa.* (N. America.)
50. " *radiata.* } (California.)
" *Sabiniana.* }
Platymiscium platystachyum. (Tropical America.)
Pseudotsuga macrocarpa. } (California.)
Sequoia gigantea. }
55. *Spathelia simplex.* (Jamaica.)
Swietenia macrophylla. } (C. America, W. Indies.)
" *Mahagoni.* }
Tecoma serratifolia. (W. Indies.)
59. *Widdringtonia Whytei* (Natal.)

Bombay and Sind.

Cæsalpinia brevifolia. (Chile.)
Castilloa elastica. (Mexico.)
Cinnamomum Camphora. (China, Japan.)
Eucalyptus Globulus. } (Australia.)
5. *Grevillea robusta.* }
Hevea brasiliensis. } (Brazil.)
Manihot Glaziovii. }
8. *Pithecolobium Saman.* (Tropical America.)

Bengal and Assam.

Catalpa speciosa. (N. America.)
Cryptomeria japonica. (Japan.)
Eucalyptus Globulus. (Australia.)
Hevea brasiliensis. } (Brazil.)
5. *Manihot dichotoma.* }
" *Glaziovii.* }
7. *Swietenia Mahagoni.* (C. America, W. Indies.)

United Provinces.

Acacia decurrens. (Australia.)
Catalpa speciosa. (N. America.)

Cryptomeria japonica. (Japan.)
Eucalyptus citriodora.
5. „ *Globulus.* (Australia.)
„ *robusta.*
„ *rostrata.*
Prosopis pubescens. (America.)
9. *Prosopis* (species not known).

Punjab.

Acacia dealbata.
„ *decurrens.* (Australia.)
„ *melanoxylon.*
Acer Saccharum. (N. America.)
5. *Catalpa speciosa.*
Castanea sativa. (Europe, Japan.)
Cryptostegia grandiflora. (Tropical Africa.)
Eucalyptus amygdalina.
„ *calophylla.*
10. „ *Globulus.*
„ *goniocalyx.*
„ *Gunnii.*
„ *hæmastoma.*
„ (*lanceolata ?*).
15. „ *obliqua.* (Australia.)
„ *pauciflora.*
„ *resinifera.*
„ *rostrata.*
„ *rudis.*
20. „ *Stuartiana.*
„ *tereticornis.*
„ *viminalis.*
Leucæna glauca. (Tropical America.)
Pinus halepensis. (Mediterranean region.)
25. „ *Jeffreyi.* (California.)
„ *Pinaster.* (Mediterranean region.)
„ *ponderosa.* (N. America.)
Pseudotsuga Douglasii.
Quercus Robur. (Europe, W. Asia.)
30. „ *rubra.* (N. America.)
Robinia Pseud-acacia.
32. *Salix babylonica.* (Caucasus, N. Asia.)

Central Provinces.

Catalpa speciosa. (N. America.)
Combretum (*speciosum* ?). (S. Africa.)

Cryptomeria japonica. (Japan.)
Eucalyptus cordata. (Tasmania.)
5. ,, *resinifera.* } (Australia.)
Grevillea robusta. }
Lonchocarpus speciosus. (S. Africa).
Pinus ponderosa. (N. America.)
9. *Pterocarpus erinaceus.* (Tropical Africa.)

BURMA AND SHAN STATES.

Acacia dealbata. (Australia.)
Albizzia moluccana. (Molucca Is.)
Castilloa elastica. (Mexico.)
Catalpa speciosa. (N. America.)
5. *Cinnamomum Camphora.* (China, Japan.)
Coffea sp.
Cupressus Lawsoniana. (N. America.)
,, *macrocarpa.* (California.)
Eucalyptus citriodora. } (Australia.)
10. ,, *Globulus.* }
Funtumia elastica. (W. Africa.)
Grevillea robusta. (Australia.)
Hevea brasiliensis. (Brazil.)
Larix europæa. (Europe, N. Asia.)
15. *Manihot dichotoma.* } (Brazil.)
,, *Glaziovii.* }
Mimusops globosa. (Tropical America.)
Palaquium Gutta. (Gutta-percha tree of Malaya.)
Pinus canariensis. (Canary Is.)
20. ,, *Cembra.* (S. Europe.)
,, *cembroides.* (America.)
,, *halepensis.* (Mediterranean region.)
,, *insignis.* (California.)
,, *montana.* (S. Europe.)
25. ,, *palustris.* (N. America.)
,, *Pinaster.* } (Mediterranean region.
,, *Pinea.* }
Pterocarpus dalbergioides. (Andaman Is.)
Sequoia sempervirens. (California.)
30. *Swietenia Mahagoni.* (C. America, W. Indies.)
31. *Willughbeia firma.* (Malaya.)

Economic results of work very small.

7. The first point which strikes one on looking through the above list (which makes no claim to be complete and which, for instance, does not include the work done by the Forest Department in some Provinces in connection with fruit culture) is that

this question of cultivating exotics is one in which Forest officers in all Provinces take considerable interest. When it is considered, however, that this work on a more or less extensive scale has been persistently carried on for the last 30—40 years, the further fact stands out clearly, *viz.*, that the economic results of value obtained from these operations have been very small. The expenditure on the experimental cultivation of various exotics in a single Division of one Province during the period 1903—10 is reported to have been Rs. 4,108. This gives some idea of the amount of money, time, and trouble which have been given to this work during the last 40 years, and it is difficult to resist the conclusion that better results would probably have been obtained had these been devoted to a study of indigenous species.

A certain amount of success has, it is true, been obtained from the introduction of the Hevea rubber and it is probable that good results will be obtained from the cultivation of Camphor. The cultivation of such trees, however, with the object of establishing industries in such products as rubber and camphor falls rather within the sphere of the planter than of the forester. The duties of the Forest Department with reference to them are usually limited to the establishment of small experimental plantations, where such are required, in order to encourage private enterprise. With the exception of this kind of work in one or two limited areas, however, it is believed that the only plantations of exotics which can be regarded as successful from the point of view of economic forestry, and which have resulted from all the work done hitherto in this connection, are to be found in the *Eucalyptus* plantations of the Nilgiris. Mr. Gamble with his great knowledge and experience of our indigenous species and in the light of a personal knowledge of the successful *Eucalyptus* plantations in Southern India records his opinion clearly and decidedly on the relative merits of indigenous and exotic species in the following words:—"A great deal has been written, urging the more extended cultivation of Eucalypts in India; but until some species is found which, with a minimum of trouble, can be grown and will thrive on poor barren soils where indigenous trees are wanting, there seems no object in spending money on their further growth. On the Nilgiris, the growth of the "Shola" trees was found to be so slow that there was danger of the indigenous growth being exhausted, and so the introduction of the quick-growing Eucalypts and wattles was an important measure. * * On the whole, how-

ever, India has indigenous trees in all the regions where it is possible to grow such exotics as the Australian Myrtaceæ, which are quite as beautiful, have better timber and are more suitable for permanent cultivation in almost all respects except that of quickness of growth."[1]

Suggestions for future work.

(8) The list given above, however, clearly shows that this question of exotics is a living and important one in the opinion of the Forest Department generally and with the object of systematising this work and of making it more remunerative than it has been in the past the following suggestions are put forward for consideration :—

Primary attention to indigenous species.

(I) The idea of replacing our valuable indigenous species on a large scale by exotics should be definitely abandoned. Every effort should be made to acquire and disseminate a more precise knowledge of the commercial value of our indigenous species, to study their requirements more carefully and to elaborate methods of treatment based thereon which shall insure healthy development and the maximum permanent yield of their most valuable products.

Decrease purely arboricultural work.

(II) Purely arboricultural work, such as the planting of ornamental trees in avenues and elsewhere, should so far as possible be carried out under the supervision of the officers in charge of the various botanical and agri-horticultural gardens of the country. To these institutions might be forwarded with advantage the seed of those exotics regarding the suitability of which for this country little to nothing is known. The plants would probably have a better chance of surviving than if dealt with by the average Divisional Forest Officer who has few facilities for work of this kind. If seeds or plants of such species are subsequently required for experimental or ornamental planting they could be obtained from the local gardens. The seed thus obtained would be to some extent that of acclimatised plants and therefore likely to give better results than the first imported seed. The experience gained in the gardens, also, regarding the conditions suitable for the species could be utilised with advantage. In connection with this class of work, however, more attention

[1] Manual of Indian Timbers, 1902, pp. 352, 353.

should certainly be paid to the qualifications of our indigenous species as valuable avenue trees and ornamental plants and which are frequently overlooked.

Collection and publication of information on useful exotics already introduced.

(III) In order to realise the maximum economic benefit from the work which has been done in the past, it is essential to arrange for the systematic collection and publication of all the available information regarding those exotics which have been introduced in the past and which distinctly promise to be of forest importance in India. Special attention for instance would be paid to those species which have grown, or which promise to grow, well in low-lying forest-encircled grasslands subject to frost and drought, on hot dry rocky slopes and plateaus at various elevations, on shifting sand, on landslips, on soil which has been hardened and compacted by grazing, on areas liable to water-logging, and in short in all unfavourable habitats where we find it difficult to obtain valuable growth of our indigenous species. Illustrations and descriptions to facilitate the identification of the species would be given, with notes on the conditions prevailing in their natural habitats, the history of their introduction into India and the conditions under which they have been found to thrive, the places where seed may be obtained and their economic uses. With this object, it is proposed to issue a series of publications from this office, so far as possible with the co-operation of local Forest officers and the Superintendents of the various Botanical and Agri-horticultural Gardens, of which the present paper, dealing with *Prosopis juliflora*, DC., may be regarded as the first.

Future cultivation of exotics to be on a limited scale in selected localities.

(IV) It is advisable to limit the future cultivation of exotics, as far as possible, to those special localities where we have difficulty in obtaining valuable growth of our indigenous species and where better results might possibly be obtained with carefully selected exotics. The following may be mentioned as examples of such areas.

(*a*) Bare rocky slopes and plateaus which are, as a rule, essentially dry habitats, only suited for the development of xerophilous species.

The majority of our indigenous species which can thrive in such localities are of little commercial value and, of the more valuable species which can be induced to grow there, the growth, under such conditions, becomes so inferior as to make them practically valueless.

(*b*) Similar in some respects to (*a*) are the forest-locked grass-plains which are common in our Indian forests and which are particularly characteristic of the Sal (*Shorea robusta*) tracts. In such localities the extremes of temperature prevent the survival of any but strongly xerophilous indigenous growth usually of minor importance.

In the case of both (*a*) and (*b*) localities it is possible that we may find what we require among the numerous valuable species of *Eucalyptus*, some of which, at least, are known to endure drought and extremes of temperature well and are thus able to thrive in strongly xerophytic habitats. In subsequent papers it is proposed to deal with those species of this genus the cultivation of which at Dehra Dun and elsewhere has given most promise of success.

(*c*) Landslips and shifting sands. Here as in other cases, of course, care must be taken not to overlook the value of indigenous species, such as *Casuarina equisetifolia* for instance, in the afforestation of sandy littoral tracts.

(*d*) On compact, badly-aerated soil.

(*e*) Localities where very rapidly growing species are required to produce a larger volume of wood per unit of area than can be obtained from indigenous species.

Some of the Australian Acacias and Eucalypts must be considered here and perhaps also *Albizzia moluccana*, Miq., which is now being grown experimentally at Dehra Dun.

Information required regarding the localities.

(V) With a clear idea, now, as to the precise areas in which, and the purposes for which, we desire to introduce exotics, it is advisable to ascertain, as far as possible, the essential features of the localities with reference to their power of supporting a particular type of vegetation and especially as regards :—

(*a*) Character of the soil, sand, loam or clay ; approximate depth of soil and slope.

(*b*) Depth of water-table.

(*c*) Whether soil well-drained, or liable to water-logging, as is for instance the case in low-lying heavy soil which has been trampled and compacted by cattle in wet weather.

(*d*) Presence of water due to percolation from streams or canals.

(*e*) Annual rainfall and its monthly distribution.

(*f*) Whether sheltered, or exposed to strong winds.

(*g*) Elevation above mean sea-level and aspect.

(*h*) Temperature, especially the maxima and minima temperatures at different seasons and liability to frost.

(*i*) Humidity of the air.

(*j*) Liability to snowfall and at what season. Australian species of Acacia and Eucalyptus planted in the Himalayas have frequently proved unable to withstand the snowfall.

(*k*) The general type of the existing vegetation, *i.e.*, whether xerophilous, mesophilous, or hygrophilous, and its periodicity.[1]

Information required regarding the exotics.

(VI) Having ascertained, so far as possible, the conditions of our localities as detailed above, it is advisable to collect information under heads (*a*) to (*k*) regarding the conditions which characterise the natural habitats of those exotics which, from their economic reputation, appear to be desirable. Attention must also be paid to the following points :—

(*a*) The characters, xerophilous or otherwise, of the plants, many of which can be recognised in an ordinary herbarium specimen. These will to some extent compensate for lack of precise information regarding the habitat; (*b*) the periodicity of the plants and natural time for germination of seeds. The natural period of vegetative activity is of great importance, for plants which can, for instance, withstand extremes of temperature when leafless, may be killed by comparatively moderate temperatures when in leaf; (*c*) whether in nature they usually grow best in the shade of other plants or are able to directly

[1] For an explanation as to what is here meant by such expressions as "xerophilous type of vegetation" see *Indian Forest Memoirs, Botany, Vol. I, Part I, Introduction,* especially pp. 5—11 and 22—28.

afforest open areas; (*d*) any method of cultivation which may have been proved to give good results and best season for sowing and planting; (*e*) whether in nature they usually occur pure or in admixture with other species. If the latter, with what species do they usually grow best.

Cultivation to be in strict accord with economic principles.

(VII) The experimental cultivation of those exotics which seem most likely to succeed should be at first on a small scale only. This work must, however, be carried out strictly as an economic forest operation, and the expenditure per acre should be kept within such limits as shall insure a financial profit even if but moderate success is attained. So far as possible, in all cases, the most suitable indigenous species should be cultivated with the exotics under precisely similar conditions to give an idea of their comparative values.

9. It is not of course assumed that all the important factors of a plant's environment have been included under heads (V) and (VI) of the last paragraph, but it is maintained that those factors which are, as a rule, the limiting factors in India and on which, in the majority of cases, success or the reverse depends, have been considered, more especially those of the temperature and available water-supply, which latter again chiefly depends on the soil, rainfall, temperature, humidity of air, and winds. It may be argued that it is quite impossible to obtain the detailed information set out above, but the answer to this is that efforts ought to be made to obtain information as complete as possible seeing that, as a general rule, the more care taken to place a plant in a suitable and natural environment, the greater will be the chance of economic success. Again, it may be argued that, even if the information asked for is supplied, it will be still difficult to select the most suitable plants since it is not known how great a variation in any particular factor, such as rainfall, or temperature, recorded in the artificial, as compared with the natural, habitat, will suffice to prevent growth in the former. Again, considerable variation in one factor may be of little importance provided it is accompanied by a considerable difference in some other factor. Thus many plants can withstand extremes of temperature in some localities which would prove fatal in others. A copious water-supply by enabling a plant to transpire

actively may render unusually high temperatures innocuous, while absence of drying winds may greatly decrease the damage done in cold seasons when the soil temperature is low. Again, species which grow well in a humid climate on light soils may do equally well in a drier climate on heavy soils.

Difficulties will no doubt arise and mistakes will no doubt be made, but if due care is taken it should be possible to prevent a number of mistakes which have occurred in the past (such as in introducing hygrophilous evergreen species into xerophytic localities where damage by frost and drought is frequent), and thus to prevent a considerable waste of time and money.

10. Since 1908, this office, at the instance of the Government of India, has arranged with the co-operation of local Forest officers for the supply of such seed of our indigenous species as may be indented for by British Colonies, Foreign Governments, Institutions, etc. It is hoped that, in return for such seeds, the information under paragraph 8 (VI) above, required by local Forest officers who are interested in this subject, may be obtained from foreign correspondents regarding valuable exotics and the conditions which are most likely to suit their growth. Since 1908 a quantity of seeds of our indigenous species has been supplied through this office to various parts of Africa, Mauritius, Europe, United States of America and the Philippines.

11. With regard to the present paper, the writer is indebted to the Forest officers in the different Provinces for information regarding the various exotics cultivated in recent years and also to Mr. A. C. Hartless, Superintendent of the Government Botanical Gardens, Saharanpur, for information regarding the introduction of *Prosopis juliflora* and its growth at Saharanpur.

Prosopis juliflora, DC.

(*var.* glandulosa, *Sarg.*)

Taxonomy. Bentham (*Mimoseæ* in *Trans. Linn. Soc.*, Vol. XXX, 1874, and again in Martius' *Flora Brasiliensis*, 1876) takes a wide view of this species, *P. juliflora* DC., and reduces all the following names to synonyms :—

Prosopis horrida,	Kunth.	*Prosopis Siliquastrum,*	DC.
,, *dulcis,*	Kunth.	,, *domingensis,*	DC.
,, *inermis,*	H. B. & K.	,, *bracteolata,*	DC.
,, *pallida,*	H. B. & K.	,, *affinis,*	Spreng.
,, *cumanensis,*	H. B. & K.	,, *glandulosa,*	Torr.
,, *flexuosa,*	DC.	,, *odorata,*	Torr.
,, *fruticosa,*	Meyen.		

If this view of the limits of the species is maintained there are names which should apparently take precedence of *P. juliflora,* DC., *e.g.*, *P. pallida,* H. B. & K. This latter form is a native of South America and is said to have " been successfully grown in Ceylon. Its pods are considered of high value as a tanning material, containing, it is said, as much as 90 per cent. of tannic acid. They are known by the name of 'Balsamocarpon,'" (*Indian Forester,* IV, p. 153). Professor C. S. Sargent (in *Manual of the Trees of North America,* 1905, p. 548) deals with the North American forms of the species under the name *P. juliflora,* DC., of which he has two varieties :

(*a*) *glandulosa,* calyx usually glabrous, leaves glabrous, leaflets often 2 *in.* long.

A round topped tree often 20 feet high, with a trunk a foot in diameter, and long gracefully drooping branches.

(*b*) *velutina,* calyx villose, leaves pubescent, leaflets $\frac{1}{4}$—$\frac{1}{2}$ *in.* long.

A tree often 50 feet high, with a trunk 2 feet in diameter, and heavy irregularly arranged usually crooked branches.

The specimens in Herbarium Dehra agree well with the description of variety *glandulosa* and this appears to be the form which has been chiefly cultivated in India up to date.

The following brief description has been drawn up from the specimens in Herbarium Dehra of plants cultivated in India :— Description.

Habit—Small tree or large shrub.[1] With or without straight, stout, more or less extra-axillary spines ½—2 *in.* long.

Leaves—Alternate, or fascicled on stunted branches, 2-pinnate.

Stipules small, lanceolate to subulate, deciduous or persistent.

Petiole ¼—5 *in.* long, glabrous.

Rachis (excluding petiole) ¾—2½ *in.* long, glabrous, apex spinescent, a gland at base of each pair of pinnæ.

Pinnæ 1—2 pair, opposite, 2—6¾ *in.* long, with or without glands at base of upper leaflets.

Leaflets 9—20 pair, opposite, sessile or subsessile, linear, reticulate, apex acute or obtuse, glabrous.
Length ¼—1½ *in.*
Width 0·05—0·25 *in.*

Flowers—Shortly pedicelled in cylindrical, spiciform, axillary racemes.

Peduncle ¼—1 *in.*

Raceme 2—3·5 *in.* long (excluding peduncle).

Bracteoles small, obovate to rounded, sparsely villous, deciduous.

Pedicels 0·02—0·03 *in.*

Calyx valvate, campanulate, ½ the corolla, 5-toothed or slightly lobed, a few short hairs, chiefly near the margins of the teeth, otherwise glabrous.

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[1] Professor C. S. Sargent, *l.c.*, notes as follows on the habit of this species: "a low tree, with a large thick taproot descending frequently to the depth of 40—50 ft. and furnished with radiating horizontal roots spreading in all directions and forming a dense mat, a trunk 6—8 *in.* diameter, divided a short distance above the ground into many irregularly arranged crooked branches forming a loose straggling head * * more often a shrub, with numerous stems only a few feet high." The following information is available regarding the growth of the plant in India : "The trees (at Umballa and Jalundur) were about 3 or 4 ft. high in about a year's growth, and had long straggling branches." (*Indian Forester*, Vol. V, p. 332.) "The Saharanpur plants are 6 years old, and are bushes with a loose straggling habit from 15 to 20 ft. high, but with no appearance that would lead one to suppose they will grow into trees from 40 to 60 ft. high, and produce marketable timber." (*Indian Forester*, Vol. X, p. 369.) See also note on page 4 above. Most of the plants now in cultivation in India appear to have been raised from seed obtained in North America. Information does not seem to be available as to whether better results in the way of height growth and timber production were obtained from the consignment of seed sent from Jamaica, see p. 3 above.

Petals valvate, 5, subequal, oblong to narrow-elliptic, ultimately free to base, 0·1—0·13 *in.*, more or less villous within, especially towards the apex, glabrescent without.

Stamens 10, free, shortly exserted.

Anthers 0·03 *in.*, versatile, crowned with a stipitate deciduous gland at apex.

Ovary stipitate, densely villous with long white hairs, stigma minute, terminal.

Ovules about 17.

Fruit—Linear, straight or falcate, at first compressed, ultimately subterete, slightly constricted between the seeds, apex long acuminate, stipe 0·2—0·7 *in.*

Length 5—8 *in.* (excluding stipe).

Width 0·25—0·35 *in.*

Indehiscent, exocarp thin, rigidly coriaceous, mesocarp pulpy, endocarp cartilaginous surrounding each seed separately and thus forming distinct nut-like joints.

Seeds albuminous.

Explanation of Plate.

Fig. 1. Flowering twig × $\frac{4}{5}$.
" 2. Immature pod × $\frac{4}{5}$.
" 3. Mature pod × $\frac{4}{5}$.
" 4. } Flower × 3.
" 5. }
" 6. Calyx × 3.
" 7. Petal × 3 ; (*a*) upper surface, (*b*) lower surface.
" 8. Stamens × 5.
" 9. Ovary × 3.
" 10. Interior of pod showing nut-like joints × $\frac{4}{5}$.
" 11. A single nut-like joint of endocarp × $\frac{1}{1}$.
" 12. The same, open, showing the contained seed × $\frac{1}{1}$.
" 13. Longitudinal section of seed showing albumen × $\frac{1}{1}$ approx.
" 14. Embryo × $\frac{1}{1}$ approx.
" 15. Leaflet { (*a*) upper surface / (*b*) lower surface } × $\frac{4}{5}$.

Distribution and conditions of habitat outside India.

Bentham (*l.c.*), taking the wide view of the species, gives its distribution as "West tropical and subtropical North and South America; very abundant from Buenos Ayres and Chile, along the Andes, to

Mexico and Texas, and frequently planted." As regards N. America the tree is described as "one of the characteristic trees of the lower Sonoran zone, an area where the conditions as to rainfall and climate range from arid to semi-arid—that is, the rainfall varies from less than 10 to about 25 inches per annum."—(*U. S. Dept. Agric. Bull. 16* by J. G. Smith, 1899, p. 18.) It is found in the United States in Texas, Kansas, New Mexico, Arizona and Southern California. The tree is common in Jamaica where it is known as *Cashaw* and is described as "an admirable tree (often attaining a height of 40 to 60 feet) to grow in dry gravelly soil, and in situations where rain does not fall for months together."—(*Indian Forester,* Vol. X, p. 293.) A form of this variable species was introduced from Mexico into the Philippines, where it is now said to be "abundant along the sea-shore forming dense thickets immediately back of the beach."—(*Philippine Journal of Science,* Vol. 1, p. 62.) This form has been given the name of *P. Vidaliana,* Naves, it being noted that "while it is undoubtedly allied to *Prosopis juliflora,* and may possibly be interpreted as an extreme form of that variable species, it is considered best to retain it as a distinct species for the present."—(*Philippine Journal of Science,* Vol. V, p. 32, 1910.)

History in India.

The first consignment of seed of this species appears to have been sent to India through Kew and the India Office in 1877, under the name of Mesquit Bean and the seed was said to be obtainable from the Consuls in San Francisco and Galveston or "any town in the Gulf of California." Considerable uncertainty appears to have prevailed as to the identification of the species sent which was at first said to be *P. pubescens* and then "probably *P. glandulosa.*" In 1878 two further supplies were received which were "supposed to be *glandulosa*" (see *Indian Forester,* Vol. V, pp. 329—332).

Both *P. pubescens,* Benth, and *P. juliflora,* DC., are apparently known by the name of Mesquit Bean and both occur in Texas, New Mexico, Arizona, North Mexico, and California. It appears doubtful whether any trees of the true *P. pubescens* are now in cultivation in India. It is said to have been tried in the Saharanpur garden in 1878-79 where "it proved a complete failure. The seedlings were very susceptible to damp, and died off while still in a young seedling stage during the first rainy season."—(*Dept. Land Records and Agric. U. Ps. Bull. 21,* 1906, p. 32.)

With reference to this failure, however, it is interesting to point out that, in a letter dated 14th December 1911 to the writer, Mr. A. C. Hartless, the present Superintendent of the Saharanpur Botanical Garden, notes that according to the garden records the plants were "too large for sending out" on 18th September 1878 and remarks that "they evidently throve while in the pots, but died after planting out. Presumably bad drainage was at fault. My own experience is that failure of this nature is no positive criterion of what the result may be on different soils to ours."

P. pubescens can be readily distinguished from *P. juliflora* by its peculiar pod which is "twisted with from 12—20 turns into a narrow straight spiral 1—2 *in.* long" (Prof. Sargent, *l.c.*, p. 551).

P. juliflora is said to have "succeeded at Lahore, in the Changa Manga Plantation (and a few trees elsewhere), at Sakesar (one of the highest points of the Salt Range, Shahpur District) and at Amritsar. A later supply succeeded fairly (to the extent of 42 trees) in Hushyarpur itself, and some in Unah. Twelve trees in the garden at Umballa were in flower in May 1879, and some 30 trees at Jalundur."—(*Indian Forester*, Vol. 5, p. 332.)

"It appears to be growing well in the Madras Presidency."—(*Indian Forester*, Vol. 5, p. 117.)

"Seeds and plants of this tree have been extensively distributed from the Saharanpur Botanical Gardens within the last few years under the name of "Mesquit Bean" * * it thrives in the poorest of soils."—(*Indian Forester*, Vol. X, p. 369.)

"The plant is thorny and can be recommended for a rough hedge, or for planting in groups on waste lands. It has proved to be drought-resisting and thrives in all soils under very little care. It is easily propagated by sowing the seeds immediately after being gathered or at any time during the summer months."—(*Dept. Land Records and Agric. U. P. Bull. No. 21,* 1906, p. 32).[1] Specimens of this species from plants which have been grown at Sibi and Quetta (Baluchistan) are in Herb. Dehra.

The greatest success, however, appears to have been obtained in Sind as will be seen from the following :—" The *Prosopis glandulosa* is a decided success. I propose importing large quantities of the seed of

[1] Mr. A. C. Hartless, Superintendent of the Saharanpur Botanical Gardens, informs me that this species is still growing well at Saharanpur where seed may be obtained.

this tree."—(Ann. Forest Report of Sind Circle for 1883-84, p. 13.) "*Prosopis glandulosa* reproduces itself from self-sown seed and suckers and it might be made to form part of the ordinary forest vegetation."—(Ann. Forest Report of Sind Circle for 1891-92, p. 10.) "The introduction of *Prosopis glandulosa,* the seed of which was obtained from Government in 1877-78, into this Province has proved a distinct success. * * * in the form of its growth it is more in the nature of a shrub than a tree, and it may now be seen growing luxuriantly all about Miani near Hyderabad and especially over the scene of the old battle-field. The Miani Monument Garden for some years could not be improved because of the disastrous inroads of drifting sand which impeded the introduction of almost all growth in it. But *Prosopis glandulosa* by its natural regeneration over the Miani plain seems to have stepped in and saved the situation. Its pods are eaten by goats and these animals have been the means of distributing the seed over the area surrounding the monument where it has germinated and the resulting growth has served as an excellent sand-binder and screen against the further inroads of drifting sand. The improvement of the Miani Monument Garden, therefore, now can be proceeded with without any further difficulty, and it is hoped to convert it ultimately into an attractive public resort. Needless to say that the artificial regeneration of *P. glandulosa* will be encouraged. It is very well suited for the reboisement of high and dry lands, and like *Prosopis spicigera* in such situations remains in almost full leaf all the year through. Its branchwood will form a useful fuel."—(Ann. Forest Report of the Circles of Bombay Presidency for 1910-11, p. 44.)[1]

Economic importance. Fodder.

The following account refers to the value of this species from a fodder point of view in the U. S. America :—

"It normally produces from one to three crops of beans every year. The pods are filled with a sweetish pulp, which causes them to be much sought after when ripe by cattle and horses, * * The beans are produced in greatest abundance during the dry years, and are then very

[1] Since the above was sent to Press, Mr. J. Copeland, Conservator of Forests, Punjab, has kindly sent the following note regarding the success of this species in the Punjab :—"*Prosopis juliflora* which was introduced into the Punjab about 1878, and has been grown on a limited scale in the Pabbi Hills' Reboisement area, is now regenerating freely in the Pabbi and is likely to be a very useful plant for reboisement work in dry localities. Arrangements have been made to cultivate it on a large scale in the reboisement areas which have recently been started."

valuable forage. The sweet pods are greedily eaten by cattle, and prove almost as fattening as barley or other grain. The yield varies from a few bushels to often 75 or 100 bushels of ripe pods from the trees on an acre of land. The seeds are hard and indigestible and remain in the dung when the pods are eaten by cattle. They then seem to be even more sure of germination than when the pod is left to rot on the ground. By this means alone this tree is spreading rapidly each year over new territory, the seeds being scattered far and wide by all classes of animals that feed on the pods."—(*U. S. Dept. Agric. Bull No. 16* by J. G. Smith, 1899, p. 18.) This species is said to be spreading and encroaching on the grasslands in the U. S. America as a result of fire-protection. The following information refers to this tree in Jamaica :—

" The pods are of a sweetish succulent character eagerly sought for by cattle : indeed in some parts of this island during droughts they subsist largely on them. For horses and mules the pods are also admirable food, but I would add that in their case it is very undesirable to allow them to feed upon the pods immediately after they have been exposed to rain, as ill effects have been known to arise from the partially germinated seeds being taken into the stomach, causing great pain and not unfrequently death ; this last occurrence, however, is so rare that it need not enter into the calculations of the planter. The tree fruits during dry weather when there is little probability of rain, and if the pods are collected and stored in a dry place they will be ready at hand in a sound state for all forage purposes. When thus stored, the pods, instead of being given whole, are often broken up or ground, when they answer admirably instead of corn, oats, etc."—(*Indian Forester,* Vol. X, p. 293)

Wood.

Prof. C. S. Sargent (*l.c.*, 1905, p. 549) describes the wood as " heavy, close-grained, rich dark-brown or sometimes red, with thin clear yellow sapwood ; almost indestructible in contact with the soil, and largely used for fence-posts, railway-ties, the underpinnings of buildings, and occasionally in the manufacture of furniture, the fellies of wheels, and the pavements of city streets ; the best fuel of the region, and largely made into charcoal." As regards the timber-yield the var. *velutina* which attains the largest dimensions and which is a native of the hot valleys of Southern Arizona and Sonora would almost certainly give better results than the var. *glandulosa* which is now in cultivation. Possibly the Jamaica tree (see p. 3 above) also belongs to the former

variety. *P. pubescens*, Benth, is said to be "a tree 25—30 ft. high, with a slender trunk sometimes a foot in diameter * * wood heavy, exceedingly hard, close-grained, not strong, * * used as fuel and occasionally for fencing."—(Prof. Sargent, *l.c.*, p. 551.) This species, therefore, does not appear to be so valuable as *P. juliflora*.

Gum-arabic.

A gum, resembling gum-arabic, exudes from the stems of *P. juliflora*. The following report by Dr. Hooker probably refers to the gum of this species : "Mesquit Gum. Mr. F. Kalteyer, treasurer of the Agricultural and Industrial Association of Western Texas, says the Mesquit Gum of that region is almost identical with gum-arabic, having been in use there for medicinal and technical purposes, especially in the preparation of mucilage, gum-drops, jujube-paste, etc. The past year it has become an article of export, some 12,000 lbs. having been gathered in Bexar country, and as much more between that and the coast."—(*Indian Forester*, Vol. V, p. 330.)

Dye.

The following extracts from Laman's *Hortus Jamaicensis* were sent to India with the seed in 1877:—

"The dyers use the husk of the pods to dye black; they also soak some of the pods all night in water, then mix a little alum with it, and boil it to a due thickness which makes a very fine black and strong ink. I have often made it and wrote with it, and observed that it never fades or turns yellow, as copperas ink will. I carried some of the pods with me to England in 1717, and gave them to a dyer who tried them and said they exceeded galls for dyeing of linen, and if they would come as cheap, would be preferable."

Afforestation.

"The planters made fences with it in the southern lone lands and savannahs; but its seed dispersing about soon sprouted spontaneously, and now it overruns vast tracts of land, and maintains its ground so firmly that so long as the least particle of the root remains, it never ceases throwing up its thorny plants, while it is next to impossible to eradicate it entirely from a piece of land in which it has once flourished."

Summary.

This plant is a strongly xerophilous species, well adapted to thrive on dry soils and in arid districts. It is likely to be useful as a sand-binder and also as a pioneer in afforesting dry grasslands[1] and waste

[1] Unfortunately no definite information appears to be available, at present, as to the plant's ability to withstand frost which is a very important factor in many of our forest grasslands.

areas where more valuable species cannot be got to grow. Its pods are a useful fodder, especially in dry years of scarcity and its wood is of considerable value (especially of the variety *velutina* which is said to attain a height of 50 ft. and diameter of 2 ft.).

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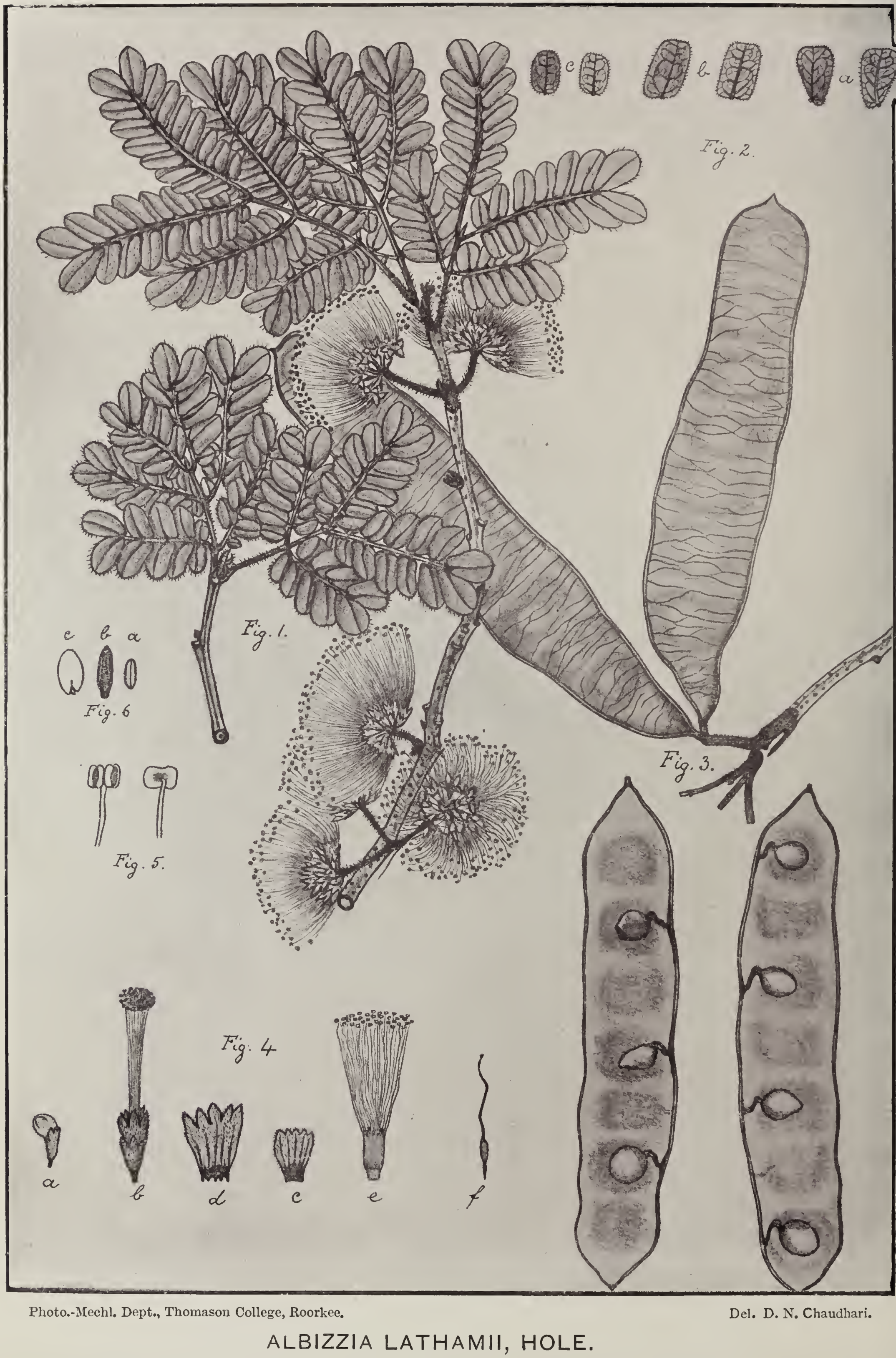

Photo.-Mechl. Dept., Thomason College, Roorkee. Del. D. N. Chaudhari.

ALBIZZIA LATHAMII, HOLE.

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INDIAN FOREST RECORDS.

Vol. IV] 1912 [Part IV

ALBIZZIA LATHAMII, *Hole*, sp. n.

By R. S. HOLE, F.C.H., F.L.S., F.E.S.,
Botanist, Forest Research Institute, Dehra Dun.

Introduction.

In April 1911, specimens of an *Albizzia* were sent to Dehra Dun for identification (from the Tinnevelly District of Madras) by Mr. H. A. Latham, Deputy Conservator of Forests. The specimens did not agree with any of the species belonging to the genus, regarding which literature or herbarium material was available at Dehra Dun. On specimens being sent to Kew, Colonel Prain, with reference to them, kindly informed the writer that they "have not been matched with any of the material in Herb. Kew." At the writer's request, Major Gage very kindly compared specimens of this tree with the material in the Calcutta Herbarium and discovered that the plant was there represented by two sheets of the Kew distribution (1866-67) of Wight's Southern Indian specimens under the No. 898. Both these sheets have been named in manuscript *Albizzia odoratissima*, Benth. One of these sheets is a mixture of the true *A. odoratissima* and the present plant, the other sheet is this plant entirely. So far as the writer can discover, 94 species appear to have been described in the genus *Albizzia* up to date, exclusive of synonyms and accepting the genus as defined in the *Genera Plantarum* of Bentham and Hooker (Vol. I, 1865) and more recently by Taubert in Engler and Prantl's *Pflanzenfamilien* (III. 3, 1891). Descriptions of all of these have been carefully checked and it is believed that the present plant is undoubtedly a new and distinct species.

The following is the description of this tree :—

Albizzia Lathamii, *Hole,* sp. n.

Description. Hitherto confused with *A. odoratissima,* Benth., from which it differs considerably in leaves, inflorescence, flowers and pod. From the description, appears to be allied to the African *A. pallida,* Fourn., from which it differs in fewer, smaller leaflets and in the inflorescence.

An unarmed much-branched small tree, as a rule not exceeding 25 *ft.* in height and 7 *in.* in diameter.

Young shoots tawny-pubescent.

Bark of branchlets purplish-red, white-lenticellate.

Leaves alternate, evenly 2-pinnate, petiolate.

Petiole length 0·2 *in.* to 1·5 *in.* pubescent and with a large gland at $\frac{1}{4}$ to $\frac{1}{2}$ its length from the base.

Primary rachis (excluding petiole) 0·3 *in.* to 3·2 *in.*, long, pubescent and with a gland below the upper 1 to 5 pairs of pinnae.

Pinnae opposite, 2 to 7 pairs, 0·5 *in.* to 2 *in.* long, pubescent, with, or without, a distinct gland below the upper 1—3 pairs of leaflets.

Stipules subulate, 0·1 *in.* long, pubescent, deciduous or subpersistent.

Stipels O.

Leaflets—Opposite, subsessile, 4 to 10 pairs.

Length 0·1 *in.* to 0·55 *in.*, width 0·05 *in.* to 0·35 *in.*, obliquely oblong, base truncate, apex retuse, rounded on acute. Subcoriaceous. At base 2—4 nerved, pinnately-veined above.

Midrib central to $\frac{1}{3}$ of width from upper margin. Lateral nerves 2—8, arcuately joined near the margin, with the reticulate venation indistinct above, prominent below.

Terminal leaflets large, obovate, base cuneate on upper margin, auricled on lower margin.

Basal leaflets small, often oval to elliptic with a central midrib.

When young, adpressed-pubescent above and below. When mature, sparsely adpressed-pubescent to glabrescent above, pale and more or less adpressed-pubescent below, especially on the midrib. Margin ciliate.

Flower-heads globose, 1 *in.* to 1½ *in.* in diameter, on pubescent peduncles 0·2 *in.* to 0·9 *in.* long.

Solitary, or fascicled and 2—5 together, usually at the lower leafless nodes (often on stunted leafless branches).

Very rarely in the axils of the lower leaves. (*a*)

Flowers, white, distinctly pedicelled, pedicel (*b*) 0·03 *in.*—0·05 *in.*

Calyx tubular-campanulate, valvate, 0·1 *in.*—0·18 *in.* long, mid-diameter 0·04 *in.*—0·08 *in.*, subequally 5-toothed, more or less deeply split on one side, teeth deltoid to lanceolate, 0·2 *in.*—0·04 *in.* long, puberulous or adpressed-pubescent without, especially towards the apex.

Corolla infundibuliform, 0·2 *in.*—0·3 *in.* long, subequally 5-lobed, lobes valvate, lanceolate, 0·05 *in.*—0·1 *in.* long, densely adpressed-pubescent without.

Stamens 30-50, long-exserted, filaments united at base into a tube 0·07 *in.*—0·18 *in.* long. Filaments 0·4 *in.*—0·5 *in.* long. Anthers minute, quadrate, versatile, dehiscing longitudinally.

Ovary superior, shortly stipitate, stipe (above the pedicel) 0·01 *in.* —0·03 *in.* long, glabrous to sparsely puberulous, ovules 8.

Style 0·45 *in.* long.

Pod straight or slightly curved, liguliform, compressed, dry, 2 *in.*—5 *in.* long, ½ *in.* —1 *in.* wide, opening with straight valves. Apex mucronate, acute or acuminate, base cuneate, often more or less prolonged into a distinct stipe above the thickened pedicel. Dark brown,

(*a*) The inflorescence is characteristic and this alone appears to distinguish this plant from all the other Indian species of the genus. In the latter the inflorescence is developed on the leafy shoots, either in the axils of the upper leaves or at the apex above the leaves. In *A. Lathamii*, on the other hand, the inflorescence usually appears on the old wood below the leafy shoots, often on stunted leafless branches and only rarely at the lower nodes of the leafy shoots. The two following African species which belong to the same group resemble *A. Lathamii* more or less in this respect, *viz.*, *A. Antunesiana*, Harms, and *A. anthelmintica*, A. Brongn. Of the former the author says " pedunculis solitariis vel geminis, ex axillis foliorum delapsorum ortis " (Bot. Jahrb. Vol. XXX, p. 75). Of the latter Bentham says " pedunculi axillares v. ad nodos vetustos breves fasciculati " (*Mimoseæ* p. 564), while Oliver (Fl. Trop. Afr. ii 357) notes " peduncles fascicled or solitary in the upper axils or from leafless nodes on the older wood."

(*b*) The pedicel consists of the constricted basal portions of the calyx, corolla and staminal-tube which adhere closely to the lower part of the stipe of the ovary. The measurements of calyx, corolla and staminal-tube given in the above description do not include this basal portion which is regarded as a part of the pedicel.

thin, flexible, sparsely pubescent especially on sutures, not septate between the seeds. Valves not separating from sutures in dehiscence, strongly transversely-reticulate without, reticulations uniform or more prominent near sutures. Sutures not prominently thickened.

Seeds 3-8, oval to sub-orbicular, compressed, 0·2 *in.*—0·4 *in.* long, 0·16 *in.*—0·3 *in.* wide, testa greenish-yellow smooth. Exalbuminous. Base of cotyledons sagittate.

Explanation of Plate.

Fig. 1, Flowering and leafy branches; *Fig. 2,* Leaflets, (*a*) apical, (*b*) median, (*c*) basal; *Fig. 3,* Pod; *Figs 1—3* x $\frac{4}{5}$. *Fig. 4* (*a*) bud, (*b*) flower, (*c*) calyx, (*d*) corolla, (*e*) stamens, (*f*) ovary, all x $1\frac{1}{2}$; in (*c*), (*d*) and (*e*) the basal portion, which forms a part of the pedicel of the flower, is shown, in (*f*) the basal portion of the stipe forms a part of the pedicel of the flower. *Fig. 5,* stamen x 16; *Fig.* 6 (*a*) cross section of seed, (*b*) longitudinal section of seed, (*c*) embryo, all x $\frac{4}{5}$.

Distribution.

India :—Tinnevelly and Ramnad Districts of Madras. Elevation 300—1,200 *ft. Hole* 2,946, 3,631; *Wight* 898 (in part). Mr. Latham has supplied the following interesting notes regarding this tree :—

Notes.

" Does not as a rule form a central stem. The general habit is that of *Albizzia amara,* but sturdier, and in the forest the tree is liable to be taken for *Albizzia amara* or one of the shrubby *Dalbergias.* Bark smooth and dark grey, not rough as in *Albizzia odoratissima.* Leaves when fully grown are bluish-green. Flowers early in March and often again, but to a less extent, about September. Young leaves appear at the same time as the flowers but chiefly in October during the N. E. monsoon. Never entirely leafless. Occurs in dry deciduous forest associated with *Chloroxylon Swietenia, Dalbergia lanceolaria, Dalbergia multiflora, Acacia latronum, Acacia leucophlœa, Acacia Sundra, Tectona grandis* (stunted), *Bauhinia racemosa, Albizzia amara, Balsamodendron Berryi* and *Stereospermum chelonoides.*

Grows on hard red soil containing a large quantity of disintegrating quartzite."

Acknowledgments.

In conclusion, the writer desires to express his warm thanks to the authorities at Kew, the British Museum and Calcutta Herbaria for the help given in tracing existing specimens of this plant, and in supplying copies of descriptions of species which were not available at Dehra Dun; also to Mr. Latham (after whom the species has been named) for the excellent specimens submitted.

Albizzia Lathamii, *Hole,* sp. n.

Species cum *A. odoratissima,* Benth., adhuc confusa, ab eadem tamen foliis, inflorescentia, floribus etiam legumine satis longe recedit. Description.

Ex descriptione, *A. pallidae,* Fourn., africanae affinis esse videtur sed foliolis minoribus paucioribus etiam inflorescentia differt.

Arbor parva inermis ramosissima usque ad 8 m. alta, trunci diametro ad 18 cm. Innovationes fulvo-pubescentes.

Cortex ramulorum roseo-purpureus lenticellis albis instructus.

Folia alterna pariter 2-pinnata petiolata.

Petioli 5 mm. — 4 cm. longi pubescentes, glandula magna in medio vel infra medium ornati.

Rhachis 7·2 mm. — 8 cm. longa petiolo excluso, pubescens sub apice 1—5 glandulis infra-pinnalibus instructa.

Pinnae oppositae 2—7 jugae 12 mm.—5 cm. longae pubescentes, eglandulosae vel glandulis paullo infra foliolorum 1—3 paria superiora instructæ.

Stipulae subuliformes 2·5 mm. longae pubescentes deciduae vel subpersistentes.

Stipellae O.

Foliola opposita subsessilia 4—10 juga 2·5 mm.—14 mm. longa 1 mm.—9 mm. lata oblique oblonga, basi truncata, apice acuta obtusa vel retusa, subcoriacea, basi 2—4 costata deinde pennivenia, costa mediana vel a superiore margine folioli latitudinis $\frac{1}{3}$ remota, nervis lateralibus 2—8 prope marginem arcuatim junctis cum reticulatione venularum supra vix conspicuis subtus prominentibus.

Foliola summa magna obovata basi in margine superiore cuneata in margine inferiore in auriculam producta.

Foliola infima parva saepe ovalia vel elliptica costa mediana.

Foliola juniora utrinque adpresse pubescentia supra demum glabrescentia subtus pallida plus minusve adpresse pubescentia praecipue in costa, marginibus ciliatis.

Capitula globosa circiter 2·5—4 cm. diametro, pedunculata. Pedunculi pubescentes 5 mm.—2·5 cm. longi, solitarii vel 2—5—natim fasciculati plerumque ad nodos inferiores aphyllos (saepe in ramulis brevibus aphyllis) perraro ex axillis foliorum infimorum orti.

Flores albi distincte sed breviter pedicellati, pedicellis 1 mm. longis.

Calyx tubuloso—campanulatus, 2·5—4·5 mm. longus, diametro mediano 1—2 mm., uno latere plus minusve profunde fissus, dentibus 5 valvatis subaequalibus triangularibus vel lanceolatis 0·5—1 mm. longis, extus puberulus vel adpresse pubescens præsertim versus apicem.

Corolla infundibuliformis 5—7 mm. longa, lobis 5 valvatis subaequalibus lanceolatis 1—2·5 mm. longis, extus dense adpresse pubescens.

Stamina 30—50 longe exserta, filamentis 1 cm. longis basi in tubum 2—4·5 mm. longum connatis. Antherae minutae quadratae versatiles longitudinaliter dehiscentes.

Ovarium liberum glabrum vel sparsim puberulum breviter stipitatum 8—ovulatum, stylo 11 mm. longo.

Legumen rectum vel leviter falcatum liguliforme complanatum siccum 5—13 cm. longum 1—2·5 cm. latum, valvis rectis nec elasticis nec contortis a suturis nec distinctis dehiscens, apice mucronatum acutum vel acuminatum, basi cuneatum saepe in stipitem productum pedicello incrassato insidens, subnigrum tenue flexibile parce puberulum, praecipue ad suturas, intus continuum, valvis extus undique vel praesertim versus suturas conspicue transverse reticulato-venosis. Suturae vix incrassatae.

Semina 3—8 ovalia vel sub-orbiculata complanata 5—10 mm. longa 4—8 mm. lata. Testa levis flavo—viridis.

Albumen O. Cotyledones basi sagittiformes.

India : Tinnevelly and Ramnad Districts of Madras. Elevation 300—1,200 ft. ; *Hole*, 2,946, 3,631 ; *Wight*, 898 (in part).

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PLATE I.

Pearson.—Utilization of Bamboos in the Manufacture of Paper-pulp.

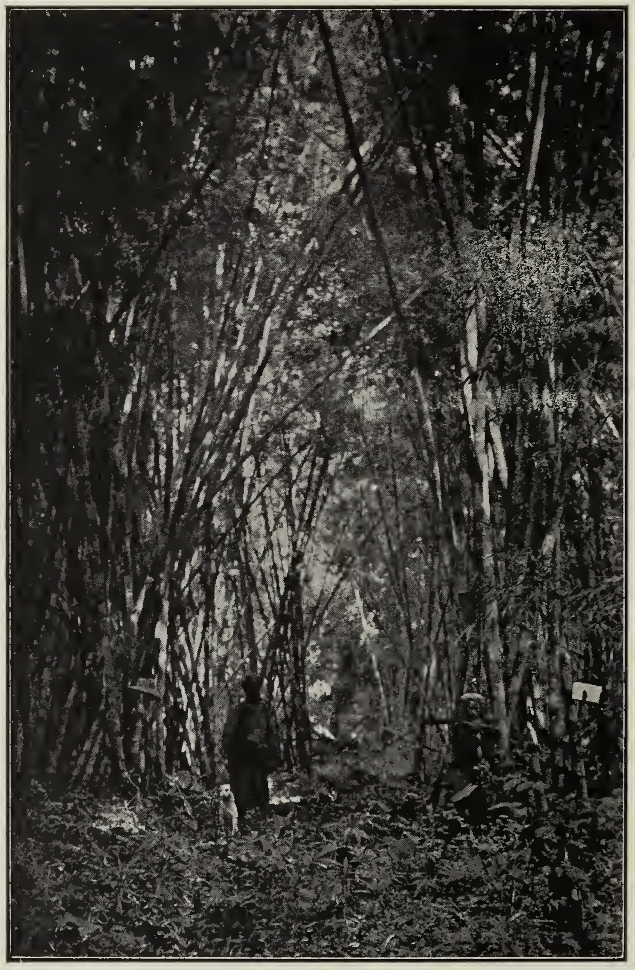

Photo.-Mechl. & Litho. Dept., Thomason College, Roorkee.

Photo. by F. A. Leete,
Deputy Conservator of Forests.

Bambusa polymorpha Forest in the Pyinmana Division, Upper Burma.

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Note on the Utilization of Bamboo for the Manufacture of Paper-pulp.

By R. S. PEARSON, I.F.S., F.L.S.,
Economist at the Forest Research Institute, Dehra Dun, India.

INTRODUCTION.

THE idea of manufacturing paper-pulp, from the raw material available from the forests of India, dates back nearly fifty years, though the only one of the many fibre-yielding plants available and now in common use for this purpose is Sabai grass (*Ischœmum angustifolium*). The possibility of manufacturing pulp from other Indian species is fully recognised, but, so far, the commercial world has considered the data available on this subject insufficient to justify starting work with those fibres. When the enquiry of which this report is the outcome was commenced in 1908, the idea was to investigate the possibility of manufacturing pulp from both timber and bamboos. As the work of getting together the necessary information proceeded, it was found that the collection of reliable data on both subjects at one and the same time was not practicable, as by so doing the enquiry would become too lengthy and complicated. It was, therefore, decided to take up bamboos as a commencement and to leave the woods until fair progress had been made with the enquiry concerning the former species. This report, therefore, deals with bamboos only.

A further restriction was also placed on the bamboo enquiry. It was thought advisable to restrict the area over which examination of the

forests should be made and to visit only a few of the most suitable localities for the purpose of collecting the necessary information. It must, therefore, be clearly understood that, though the forests, which are described in this report and which are shown on the maps, are favourable localities, from which bamboos can be extracted at cheap rates and are geographically well situated for that purpose, they are by no means the only places in British India in which it would be possible to work a pulp-mill at a profit.

Some explanation is necessary as to the limited scope of this enquiry, as regards locality. Up to date no firm or company has taken up the manufacture of pulp from bamboos in this country, and the object of this enquiry is to try and induce a firm to do so, as it is thought that if a commencement is once made and if the experiment proves, or clearly promises to be commercially successful, an industry of considerable importance may well be established. With this object in view, a limited number of localities have been chosen, which are considered suitable for the purpose, and about which definite information is given in this report.

The places selected for examination were Lower Burma and the West Coast of the Indian Peninsula, as both localities are geographically well situated for import and export purposes and also contain vast areas covered with bamboos. In Burma five localities were visited of which a careful inspection was made, namely, the Rangoon, Tharrawaddy, Pyinmana, Toungoo and Arakan Divisions. In Bombay three were inspected, namely, one partly in the North and partly in the West Kanara Forests Divisions, a second entirely in the Western Division and a third in the East Kanara Forest Division. In Madras a similar number were selected, namely, one in the South Canara Division, and one in each of the North and South Malabar Forest Divisions. The report, therefore, deals with five possible areas, from which bamboos could be exploited for the purpose of manufacturing pulp in Burma, and six on the West Coast of India.

In 1905 the Government of Burma invited Mr. R. W. Sindall, F.C.S. (London), a paper-pulp expert, to visit that country with a view to enquiring into the possibility of manufacturing paper-pulp. His report on the subject appeared in March 1906, and is one of great value. In it he laid down the lines along which further enquiry should be made, and it is largely on his proposals that the present enquiry has been based.

The writer of this report, with a view to collecting further information as to the lines on which the enquiry should be carried out, visited three of the largest paper-mills in India, and by the courtesy of the Managers of those mills, was able to ascertain what further data would be required by pulp manufacturers before they would consider the possibility of starting a mill in which bamboo would be used as the raw material. Their chief difficulty was the want of definite information as regards localities from which a large sustained yield of bamboos could be obtained at cheap rates and the possibility of manufacturing a fixed grade of pulp within a workable figure of cost. Messrs. Sindall and Raitt have proved, by their laboratory tests, that fair pulp could be made from bamboos, but the information as to supply, cost and grade of pulp when worked on commercial lines still remained to be collected.

To overcome these difficulties, the areas above mentioned were carefully inspected and extensive countings and weighings of bamboos carried out to obtain figures of yield, while to obtain a practical proof of the quality and cost of preparing pulp from bamboos, about 80 tons of raw material, of four different species of bamboos, were sent to the Titaghur Paper Mills and through the good services of the Managing Agents, Messrs. F. W. Heilgers of Calcutta, the whole was converted into pulp and eventually into paper.

The writer of this report also wishes to acknowledge the help which has been given him by various officers of the Forest Department, firms and private persons, without whose assistance it would have been quite impossible to carry out the enquiry.

While touring in various Provinces of India and in Burma he received the greatest help and kindness from all Forest Officers ; it is impossible for want of space to mention more than a few of these officers by name. Amongst those who rendered the greatest assistance were Messrs. M. Hill, C. G. Rogers, F. A. Leete, G. E. S. Cubitt, J. J. Rorie, H. L. P. Walsh, H. C. Walker, C. H. Philipp, J. V. Young, G. H. Alington and E. M. Buchanan in Burma ; Messrs. T. R. D. Bell, L. S. Osmaston, W. E. Copleston, A. G. Edie, W. A. H. Miller and G. S. Butterworth in Bombay ; and Messrs. F. A. Lodge, G. F. F. Faulkes, D. T. Barry and A. Wimbush in Madras.

Mr. Coventry, formerly Imperial Forest Chemist, carried out laboratory tests with bamboos at the Forest Research Institute, Dehra Dun, and further laboratory tests, the results of which are given

in his separate report on this subject, have since been carried out by Mr. W. Raitt, a pulp expert, to whom the writer is indebted for much help and advice.

Through the courtesy of Messrs. F. W. Heilgers, Managing Agents to the Titaghur Mills, it has been possible to have tests carried out with bamboos on a commercial scale, and it is largely due to the interest taken by them, especially by Messrs. Bryce, the General Manager of the Titaghur Paper Mills, and J. Thomson of that firm and to their report on the tests carried out by them that it has been possible to complete this enquiry. Acknowledgments are also due to Messrs. Balmer, Lawrie & Co., of the Bengal Paper Mills, for allowing the writer to visit their mills at Raneegunge and for affording him valuable information as to the present position of the pulp industry in India.

Lastly, the writer has to acknowledge, with thanks, many reports from various Forest Officers all over India, many of which contained valuable information as to possible outturn of timber and bamboos from their divisions, and though much of it does not find a place in this report, it is ledgered in the office of the Forest Economist at Dehra Dun and it will, without doubt, be of the greatest value later on, should the pulp industry develop in India.

PART I.

GENERAL DISCUSSION ON THE SUBJECT.

1. History of former enquiries carried out with a view of ascertaining the possibility of manufacturing paper-pulp from Bamboos.

Origin of the enquiry.—The idea of manufacturing paper-pulp from bamboos is not a new one. During the early seventies of the last century, Esparto grass was chiefly in use for the manufacture of paper, and just about that time the demand for cheap paper began to exceed the available supply of this grass. Paper-pulp manufacturers were therefore on the look-out for suitable substitutes and amongst others which came under their notice were conifer woods and bamboos. The conifer woods won the day, being obtainable nearer the European market, so that to-day at least three-fourths of the world's supply of paper is made from spruce and pine woods. The bamboo, however, during that period, received a fair amount of attention. The Government of India instituted an enquiry in 1873, the report on which deals with possible fibre-yielding plants, their strength and general qualities.

Enquiry by Hem Chandra Kerr in 1874.—The next publication on the subject of Indian fibres is by Babu Hem Chandra Kerr, entitled "The Cultivation of Jute in Bengal, and on Indian Fibres available for the Manufacture of Paper."

T. Routledge's enquiry of 1875.—We next find an Englishman, namely, Mr. Thomas Routledge of Sunderland, taking an interest in bamboos, at just about the time of the crisis when the supply of Esparto grass was becoming insufficient to meet the demand. It may be said that it was to this gentleman's initiative that bamboos began to be seriously thought of as a possible raw material from which to manufacture paper-pulp. He published two notes on the subject, one in 1875, entitled "Bamboo considered as a Paper-making Material" and another entitled "Bamboo and its Treatment" which appeared in 1879.

Liotard's Report of 1883.—In 1883, Mr. Liotard published a note on "Paper-making Industry in India" which deals directly with the consumption of paper in India and the United Kingdom and discusses Railway Rates, which do not, however, apply at the present time.

E. E. Fernandez's Report of 1890.—About 1890, there appeared an article in the " Indian Forester " by Mr. E. E. Fernandez, late Conservator of Forests, entitled " Wood Cellulose and Wood-pulp," in which he describes the various methods of preparing wood-pulp, especially those in vogue in French mills. The article is most instructive as explaining the methods of preparing pulp by the mechanical and soda processes.

Articles in the " Indian Forester."—Many articles have appeared from time to time in the " Indian Forester," notably two by Mr. Clutterbuck in 1899 and 1900, in which estimates are given as to the working of a mill using Himalayan conifers.

Report by S. Chas. Philipps of 1905.—In 1905, Mr. S. Chas. Philipps, M.S.C.I., read a most able article before the Society of Arts, London, on the subject of the manufacture of mechanical and chemical paper-pulp, in which he describes the various processes and their origin.

R. S. Sindall's Report of 1906.—It is not, however, until we come to Mr. Sindall's report on the " Manufacture of Paper and Paper-Pulp in Burma " that we find really definite information regarding the possibility of preparing pulp from bamboos and Indian woods. His report is divided into two parts, (i) Bamboos, and (ii) Woods. It is with the former that we are here concerned. Under Bamboos he has collected information regarding the weight of green and dry bamboos, the percentage of nodes to internodes, the size of the various species of bamboos, their market value in different places and the cost of extraction from various localities to a possible factory site. He also carried out tests by the soda process on a laboratory scale, and further tests for bleaching. He ends this report by proposing possible factory sites and discusses freights and cost of chemicals. His report is of great value and the present enquiry has been based on his suggestions as to the lines on which future investigation on this subject should be carried out. In 1909, he prepared a second note on the same subject, entitled " Bamboo for Paper-making," and this report is printed on paper made from bamboo pulp.

G. F. Richmond's Report of 1906.—A series of pamphlets have been issued by Mr. George F. Richmond of the Bureau of Science, Manila, on the subject of paper-making. The first is entitled " Philippine Fibres and Fibrous Substances : their suitability for Paper-making " Vol. I, No. 5 of June 1st, 1906. The next is Part II, of the same publication,

Vol. I, No. 10, December 1906, which treats chiefly with bamboos, and Part III (conclusion), Vol. II, No. 2, Section A, May 1907.

W. Raitt's Report of 1909.—The latest articles which are to hand on this subject appeared in "Tropical Agriculture" in 1909, under the signature of Mr. W. Raitt, a pulp expert, in which he discusses the sulphite process, as compared with the soda process, in manufacturing pulp from bamboos. In another pamphlet by the same author, in the "Paper Trade Review" of 1907, is given very useful information collected by him from sample plots taken in bamboo forests, from which figures of yield are calculated. Also interesting are the experiments made by him at the Bengal Paper Mills, Ltd., which go to confirm Mr. Sindall's tests carried out by the soda process, when that gentleman was in Burma. Raitt went further than Sindall and carried out tests on bamboo by the sulphite process, but the latest results obtained by Messrs. Raitt and Coventry in India and Mr. Richmond in Manila, go to prove that bamboo sulphite pulp is difficult to bleach. His further report on this subject entitled " Report on the Investigation of Bamboo as Material for Production of Paper-pulp" is the outcome of his experiments carried out at the Forest Research Institute, in which he describes the treatment of bamboos by the Soda and Sulphate processes. He also deals with the subject of treating the nodes together with the internodes, and the treatment of bamboos before boiling. This enquiry has been made conjointly with this report and is worthy of very careful perusal.

1908 and 1909.—In 1908, there appeared three Government publications on the subject of paper-making in India. One was by Mr. R. T. F. Kirk, I.C.S., entitled " A Monograph on Paper-Making in the Bombay Presidency" which deals chiefly with hand-made paper. Another is by Mr. D. N. Mookerji, M.A., on " Paper and Papier-Maché in Bengal" and a third bearing the same title, but dealing with the Punjab, by Mr. H. W. Emerson. In 1909, a fourth monograph also bearing the same title as the above publications, was published by Mr. J. N. Gupta, I.C.S., which deals with paper-making in Eastern Bengal and Assam. Not one of these four publications throws any light on the manufacture of paper from bamboos : they deal chiefly with hand-made paper.

There is a large amount of miscellaneous literature available on this subject, often of a very instructive nature, which has appeared in various Indian newspapers and periodicals, none of which, however, deals so intimately with the subject of bamboos as do the various reports and

articles published from time to time by Messrs. Sindall, Raitt and Richmond.

2. Present condition of the paper-pulp trade in India.

Materials used for paper-making in India.—At the present day paper is made of either waste materials such as rags, old rope, gunny bags, waste paper, etc., or from raw material such as grass, reeds, straw, wood, etc. By far the greater portion is, however, manufactured from either rags, waste paper, grass or wood. In India the chief raw material used is a grass, known as Sabai or Baber (*Ischœmum angustifolium*), which is obtained from the forests of Bengal, Orissa, Nepal and the United Provinces. No chemical or mechanical wood-pulp is made in this country though considerable quantities are imported by the existing paper-mills. The other materials used in India for the manufacture of paper are rags of poor quality, hemp, jute, gunny bags, waste paper and old rope.

Present position of affairs.—Much has appeared of recent years in periodicals and newspapers in India on the subject of the world's supply of paper. Without doubt the demand is extremely large, the present outturn according to Raitt being about 8 million tons, of which about half is produced in Europe and the remainder in America. The quantity of raw and waste material necessary to produce this amount of paper must be enormous. It is said that at least 6½ million tons of paper are produced from spruce and pines in Northern Europe, America and Canada. It is, therefore, on timber that the world at present relies for its principal supply of paper, and the question naturally arises whether the supply of timber is sufficient to meet the ever-increasing demand. The answer is without doubt in the negative. The supplies from Norway, Sweden, Denmark and Russia are not yet exhausted but already many warning notes have been sounded in that direction. The time must therefore come when the supply will run short, for in spite of strict protective measures which have been taken to ensure the preservation of the forests, the annual outturn is now in considerable excess of the possible sustained yield. Similarly, the United States have taken warning and their Government recently appointed a Commission to enquire into the subject of the supply of raw material for paper. Their report points out that matters have already gone far and proposes measures of economy. Canada still contains a vast amount of timber, but experience has

shown that no forests are really inexhaustible. History is therefore repeating itself in the matter of the supplies of the raw materials for the manufacture of paper. The first instance was when the amount of rag available was insufficient and Esparto grass came in during the fifties to save the situation. A similar difficulty arose in the seventies and this time the situation was saved by the introduction of spruce wood-pulp. Again in 1910 the position became acute. It is true that the prices of chemical wood-pulp have not as yet shown any startling upward tendency, but the continuous fall in prices of both wood-pulp and the paper made from it, came to a sudden stop five years ago, while the absence of any serious rise in prices is due to the stress of competition in the producing countries. It is believed in paper-making circles that these conditions cannot continue, and that prices must inevitably rise in the near future as the ever-increasing shortage of wood makes itself more seriously felt.

Mr. A. D. Little, Chief Scientific Officer to the American Paper and Pulp Association, in a report on this subject, emphasises "the growing scarcity of pulp wood, the continually rising price and longer haul with which paper-makers using this material are now contending, and the coming competition of new and better stocks which even now can be produced more cheaply than any bleached wood fibre."

"Wood, as a raw material, has proved so available, convenient, compact, easily handled, and heretofore so cheap, that we have been led to overlook or ignore the immense sources of other and better paper stocks which lie easily within our reach.

"We are not dealing with the perennial suggestions of visionaries who see a paper stock in every thing which has a fibre, but are instead, concerned with the serious proposals of capable technologists whose conclusions are based on careful study."

History of paper-mills in India.—The first paper-mill in India was erected at Serampore and is reported not to have been a success. The next venture was that made by the Bally Paper Mills Company in 1874; for ten years it flourished; after that it did not pay and finally went into liquidation in 1906.

At present there are six or seven paper-mills in India. The largest is the Titaghur Paper Mills Co., Ltd., with two mills near Calcutta, the older mill being situated at Titaghur and the newer mill at Kanknarrah. Their present outturn is about 14,000 to 15,000 tons of

paper per annum, made of Sabai grass, imported spruce wood-pulp and a limited amount of jute, hemp and rags.

The next most important paper-mill is situated at Raneegunge on the East Indian Railway, some 120 miles from Calcutta which belongs to the Bengal Paper Mill Co., Ltd. Their paper is made of the same materials as at Titaghur and the outturn is about 6,700 tons per annum.

Another large paper-mill exists at Lucknow, known as the Upper India Couper Paper Mills, Ltd. The raw material used in this mill is also grass, but old rags, waste paper, jute, gunny bags, and hemp here play a larger part in the manufacture of paper than is the case in the other mills.

The fourth mill of any size in India, is in the Western Presidency, at Poona, and is known as the Deccan Paper Mill Co., Ltd. The materials used in this mill are the same as elsewhere in India, though Sabai grass does not appear to play so prominent a part as in Bengal mills. The outturn is stated to be 1,000 tons of paper per annum.

A few smaller mills exist in India and a certain amount of hand-made paper is manufactured, but the total outturn of this grade of paper is not sufficient to seriously affect the market.

Imports and exports of paper in India.—The exports of Indian made paper and paste boards are at present practically *nil.* It is not impossible, however, that this state of affairs may one day be changed, when it is considered that enormous quantities of raw material suitable for the manufacture of paper, but not as yet utilized, are available in the forests of India and Burma. At present we are only concerned with the imports of paper and the outturn of the existing Indian paper mills ; the question of exporting half-stuff or paper from India may come later, but the question of supplying the existing market is the one which is at present attracting the attention of the Indian paper-makers.

The value of the imports during the last five years was as follows :—

Class of paper imported.	1905-06.	1906-07.	1907-08.	1908-09.	1909-10.
	Rs.	Rs.	Rs.	Rs.	Rs.
Printing paper . . .	21,32,459	28,33,632	36,26,984	30,96,000	33,18,292
Writing paper and Envelopes	19,15,114	22,66,714	28,09,522	23,83,354	25,53,561
Other kinds of paper . .	26,49,757	25,75,366	31,42,264	33,39,036	37,43,901
Paste, Mill and Card boards of all kinds.	3,51,648	3,35,393	3,45,492	4,45,003	5,14,495
TOTAL . .	70,48,978	80,11,105	99,24,262	92,63,396	1,01,30,249

From the above figures it will be seen that the imports have increased to the value of 31 lacs of rupees in the last five years. The most steady increase comes under " Other kinds of paper," namely, the paper which finds its way into the bazar, and it is against this imported paper that it is hoped that the Indian paper-mills will be able to compete with the help of bamboos as a raw material.

To arrive at a definite conclusion as to the relative position of affairs it is necessary to compare the present outturn from Indian mills with the amount imported into this country. The figures for the last five years are as under :—

Year.	Produced in India.	Imported.
	Rs.	Rs.
1905-06	51,86,729	70,48,978
1906-07	63,10,940	80,11,105
1907-08	72,90,385	99,24,262
1908-09	75,87,267	92,63,396
1909-10	79,11,943	1,01,30,249

It will be seen from the above statement that though the amount produced in India shows a steady increase amounting to 27 lacs of rupees in five years, the imports show an increase of 31 lacs during the same period. Again the Indian made paper amounts to 44 per cent. of the total consumption against 56 per cent. of imported paper, so that there is ample room for the further development of the Indian product, provided it can be put on the market at a somewhat lower rate than at present. There is yet another factor in favour of the Indian paper-maker. Merchants purchasing imported paper have to take up large consignments at one time and pay on delivery. This is often an inconvenience to traders, who naturally object to investing large sums of money in a commodity which does not improve by keeping and which they cannot dispose of quickly, so that when paper can be purchased for retail purposes in smaller quantities, as is possible from Indian mills, they can afford to pay up to 10 per cent. higher prices for the same article

than it is possible for them to do for large quantities of the imported material.

Cost of paper in India.—The number of grades of paper found on the Indian market is very large and market values vary considerably. The following may be taken to be the present average wholesale rates in the Calcutta market of the grades most likely to be affected by the introduction of a better supply of raw material :—

Writing paper	Rs. 400 per ton.
Superior printing paper	Rs. 330 ,, ,,
Common ,, ,, ...	Rs. 290 ,, ,,
Half bleached paper	Rs. 280 ,, ,,

From the published financial results of the companies concerned during recent years, it is clear that these prices carry a margin of profit so small that a very slight adverse disturbance of the prevailing conditions would wipe it out altogether. In the opinion of Mr. Raitt, who knows the mills well, this unfortunate state of affairs is not in the least due to deficiencies in the equipment of the mills or in their organisation and management, but solely to the lack of an adequate supply of cheap raw material.

State of Indian paper market.—To compete with the low prices of imported bazar paper it is necessary to produce a pulp at cheaper rates than can now be done with Sabai grass, mixed with a certain amount of imported wood-pulp, so that some other raw material must be found as a substitute, and from the trials recently carried out on a commercial scale it is believed that bamboos will answer the purpose.

There is another factor to be considered in connection with the price of the better classes of paper as supplied to Government and large firms by the Indian paper-mills, and that is that the cost at which Sabai grass paper can be supplied, is now so high that it is nearly possible to import equally good paper made of Spruce pulp treated by the sulphite process. In other words, the Indian high class papers are in danger of being undersold by equal grades of imported spruce paper. It is understood that this has already occurred in Madras, and that that Government have given up their Indian contracts and taken to European-made paper. This is an extremely serious state of affairs for the Indian paper-makers.

The Indian paper-maker has therefore two interests at stake, one is to keep down the cost of manufacturing his better grades of paper so as not

to lose his present market for that commodity, and the other is to reduce the cost of production of his cheaper grade papers so as to enable him to compete successfully against the imported "News" and Bazar paper. It is hoped that it will be possible to do this with the help of bamboo-pulp.

3. General conditions necessary for the successful establishment of a paper-pulp mill.

The conditions necessary for the successful establishment of a paper-pulp mill are manifold, and can only be found in a few localities. Even in the most favourable localities some factors of minor importance, though none the less necessary, are often absent, so that the best that can be done is to choose a locality where the most important conditions to ensure success are to be found.

Conditions necessary for the establishment of a mill.—The most important conditions necessary may be summarised as follows :—

(1) That a sustained annual yield of a suitable raw material for the manufacture of pulp be available in abundance.

(2) That the cost of extraction of the same can be kept within economic limits for many years to come. For bamboos the maximum price is put at Rs. 15 per ton of dry internodes landed at the mill, but it should, generally speaking, be less. By treating the nodes also, the price can be reduced by 7 to 15 per cent., according to species, as that amount of waste will be saved by utilizing the nodes.

(3) That the raw material should have little or no local value or should be available in such quantities that the requirements of a mill do not interfere with the local demand and prices.

(4) That the crop from which the raw material is drawn be a close grown one, in other words, gregarious, so that the cost of collection, and the area over which supervision is necessary, be reduced to a minimum.

(5) That the factory site selected be such that the raw material can be floated down stream to the mill door. Further it is necessary that there be direct communication by river between the mill and sea-port in order to import the necessary chemicals and coal and export the manufactured pulp. It is

preferable that the lead from the forest to the mill and from the mill to the sea-port be as short as possible though the latter is the more important factor of the two.

(6) That lime be available at cheap rates and in large quantities.

(7) That a plentiful supply of fresh water be available.

(8) That labour in sufficient quantities be forthcoming to carry out the work of extraction and to run the mill.

(9) That the locality be reasonably healthy.

(10) That the river be not subjected to excessive floods.

In the above list of conditions nothing has been said about the sale of the manufactured produce, as it stands to reason that, provided a fair quality of pulp can be put on the market at a sea-port at a reasonable cost of production, the only limit to its sale is the economic distance to which it can be exported. As an illustration of the above, the following case may be quoted. Supposing it is possible to land a certain grade of bamboo-pulp in Rangoon at £6 per ton, it might pay to export it to Calcutta or Madras, but not to Europe, or again it might be possible to export it to Japan, in competition with European pulps now imported into that country.

From what has been said above, it will be understood that the number of localities in India and Burma which fully meet all these conditions must necessarily be limited. It is thought that certain places in Lower Burma do so, such as areas on the eastern and western slopes of the Pegu Yomas, which drain into the Sittang and Rangoon or Myitkara rivers, respectively. Again certain localities in Arakan and possibly along the Chittagong and Orissa coasts are suitable, and lastly the Malabar Coast, with its many perennial streams running down to the sea from the teak and bamboo forests of the Western Ghats.

The separate cases which have been drawn up for these various localities in India and Burma are given in Part IV of this report, and are the result of careful inspections and enquiries made on the spot and based on the necessary conditions enumerated in the foregoing paragraphs.

PART II.

BAMBOOS, THEIR MODE OF GROWTH AND THE POSSIBLE OUTTURN.

1. Species of bamboos.

Bambusa arundinacea—the Daugi bamboo of Kanara—occurs throughout the Peninsula and is found at its best in the moist forests of the Western Ghats. In the latter locality it grows to a great size, often being found 100 ft. in height and each culm of great weight. A peculiar feature of this species is that it forms a dense palisade of small armed lateral branches round the base of the clump. This palisade reaches often 6 to 8 ft. upwards from the ground and makes extraction, looking to the weight and size of the culms, an expensive and difficult matter. Another drawback to this species is the thickness of the stem-walls and the hardness and size of the nodes. On the other hand, the local wood-cutters, who are used to dealing with this class of bamboo, are quite capable of carrying out its extraction, and though the cost of doing so is relatively high per culm, their great weight compensates for the extra expenditure, so that the actual cost of collecting one ton of dry bamboo works out to about the same as that of the lighter and more easily handled species found in Burma.

Bambusa polymorpha—the Kyathaung bamboo of Burma—is one of the commonest species found in the Pegu Yomas. The culms grow to nearly as large a size as those of *Bambusa arundinacea.* They are, however, unarmed, and do not grow in so compact a mass, besides which, owing to their relatively thin walls and small nodes, they are much more easily handled. They have therefore , in all points, the advantage over the larger species, when considered in connection with the pulp industry, except that they do not yield the same quantity of raw material per culm.

Cephalostachyum pergracile—the Tinwa bamboo—is also a Burma species, found in both the Upper and Lower provinces. In the Pegu Yomas it is very plentiful, but not quite so common as *Bambusa polymorpha.* It is smaller in size than that bamboo, but, in other respects,

as far as the paper industry is concerned, it is quite as suitable for pulp as that species.

Melocanna bambusoides—the Wanwé bamboo of Arakan, Burma and Assam—is found throughout Arakan, the Surma and Assam Valleys and Chittagong. It has an entirely different habit to those above mentioned in that, instead of growing in clumps, it emerges from the ground at short intervals, each stem being at a considerable distance from the next. It is a small, unarmed, soft bamboo, rarely over 30 ft. to 50 ft. in height, weighing from 3 lbs. to 10 lbs. when dry, with thin walls and small nodes. A full description of its mode of growth is given in Part IV of this report.

2. Bamboo as a fibre-yielding plant.

Bamboos come under the Natural Order *Gramineae*, to which order also belong the grasses. The fibres formed by the vascular bundles are extremely silky and fine and if seen under a microscope show fine barbs, an important factor in the "felting" and strength of pulp made of this material. The fibres in the internodes are arranged in regular parallel lines, with no tendency to be twisted or contorted, as is the case in certain species of timber, so that they can not only be split with great ease, but also be cut up into very regular sections. Another important point is that owing to the regular arrangement of the fibres and to the bamboo being hollow, the fibre can easily be reduced by crushing to a substance not unlike tow, an alternative method of treatment to cutting the bamboos before boiling which has been proposed by Raitt. That bamboos lend themselves to either of these methods of treatment is an important consideration in obtaining uniform digestion while boiling.

The suitability of bamboo fibre for the preparation of paper-pulp has been already fully demonstrated in former years by experiments carried out on a laboratory scale by various experts. The question of the quality and grade of paper produced by the various species of bamboos is fully discussed in Part III of this report.

3. Mode of growth of bamboos.

Mode of growth of Bamboos.—In order to determine the best methods of cropping bamboos in order to obtain the largest sustained yield, it is necessary to know something about the mode of growth of the various species. It might be said with justice that this information is out of

place in such a report, were it not for the fact that there appears to be doubt, in the mind of those interested, as to whether bamboo clumpa will stand repeated cutting.

Briefly, the mode of growth is as follows. The seed on germinating sends out a small shoot in the rains, completing its full growth in two or three months. This shoot may be of the thickness of a piece of straw and from 6 inches to 2 feet high. Next rains it puts out one or more shoots slightly larger both in height and diameter than the original shoot. Then, according to the species, it either again puts out more small shoots, generally speaking larger than those of the previous year, or puts out one or two distinct stems (culms) of several feet in height, and of an inch or more in girth. After that, given a normal monsoon, each year's culms tend to increase in height and diameter until the plant reaches maturity, by which time the culms put out each year have reached their maximum size. On the flowering of the bamboo the whole clump dies and new plants spring up from the seed. (A few species are an exception to this rule such as *Bambusa lineata* and *Ochlandra stridula.*)

The various cycles at which the different species flower will be dealt with hereafter. When the mature clump puts out a new culm during the rainy season, the diameter of the culm rising from the ground is the same as that when it reaches its full length; in other words, it does not increase in girth while putting on its height-growth. It grows extremely quickly attaining its full height in a few weeks or at the most during the monsoon months.

Size of culms.—The number of culms put out by a clump varies according to its age and size and also with the species. A large vigorous clump of Kyathaung (*Bambusa polymorpha*) may put out as many as 20 new culms a year. The amount of storage material which the rhizomes or root-stock of the clump has accumulated during the period of rest is fixed so that if the clump puts out an abnormal number of culms in any one year their size will be affected and they will be little, if any, longer or of greater girth than the previous year's shoots. On the other hand, if relatively few shoots are put out and the reserve material for their growth is sufficient, the size of the new shoots may be larger than the stems of the previous year. Again, if a number of bamboo clumps are inspected, there will be found here and there abortive shoots which have never reached maturity or attained their full height. Such abnormal growth is due to the root-stock having failed to supply sufficient nourishment to the culm to enable it to attain maturity.

Number of culms put out by a clump.—The actual number of culms put out by each clump, as was stated before, varies according to the size and age of the clump. In order to fix the rotation on which it is best to cut bamboos, it is necessary to know how many stems are put out, on the average, each year, by different species. With this object in view differentiation was made between under-one-year old and over-one-year old culms, when counting bamboo sample plots on the West Coast and in Burma.

By a culm under-one-year old is understood a culm which has not gone through two monsoons. By an over-one-year old culm is understood a stem which came into existence during one monsoon and which has passed through a second rainy season.

The prevailing species of bamboo on the West Coast is *Bambusa arundinacea*. Of this species the number of new stems counted was 2,675 against 9,160 old ones or in the proportion of one new stem to every 3·42 old ones.

In the Pegu Yomas, in Lower Burma, two of the commonest species are Tinwa (*Cephalostachyum pergracile*) and Kyathaung (*Bambusa polymorpha*). Of the former, 4,047 new culms were counted in the sample plots against 11,870 old ones or in the proportion of one new culm to every 2·93 old ones. Of the latter, 4,881 new culms were counted against 20,633 old ones, or in proportion of one new culm to 4·22 old ones.

The question of the proportion of new to old culms will again be dealt with when the rotation, on which the felling cycle for bamboos should be fixed, comes under discussion.

It has been explained above that the number of new culms put out per clump depends on the size and strength of the clump during any given period of its life. In order to collect definite data on this point Mr. Buchanan, a Forest Officer in Upper Burma, carried out careful countings in two successive years in sample plots chosen by him in average bamboo forest. The following table gives the results of his experiments :—

Experiments carried out in of new culms put out annually by

Date of counting.		eight dry nter-nodes, lbs.	Yield of dry inter-nodes per acre, in lbs.	REMARKS.
Countings on 2nd November 1910.	One	..	..	Mr. Buchanan states that neither the clumps of *Cephalostachyum pergracile* nor *Bambusa pallida* are as yet mature, while those of *Dendrocalamus Hamiltonii* he classes as middle-aged.
	One	73·05	..	
	One	98·60	..	
		85·82	39,871 or 18·77 tons	
	One	..	..	
Countings on 23rd September 1911.	One	..	..	
	One	..	..	*These are the number of new culms put out during the rains of 1911.
		..	..	
		..	..	
	One	..	..	

NOTE.—He proposes to carry out f ted, to any interested persons who care to make enquiries

Experiments carried out in bamboo forests by Mr. E. M. Buchanan, Extra-Deputy Conservator of Forests, Myitkyina Division, Burma, in order to ascertain the number of new culms put out annually by various species of bamboos, and the yield of dry internodes per acre.

Date of counting.	Sample plot.	Species.	Number of clumps counted.	Number of culms counted.		Number of experimental culms cut.	Average length and mid-girth.		Total weight, in lbs.		Weight of nodes, in lbs.	Weight of dry internodes, in lbs.	Yield of dry internodes per acre, in lbs.	Remarks.
				Old.	New.		length.	girth.	green.	dry.				
Countings on 2nd November 1910.	A. One acre .	*Dendrocalamus Hamiltonii* (Wabomyetsangyc).	107	1,162	174	50	39′-6″	7·2″	1,402·5	..	..	..	..	Mr. Buchanan states that neither the clumps of *Cephalostachyum pergracile* nor *Bambusa pallida* are as yet mature, while those of *Dendrocalamus Hamiltonii* he classes as middle-aged.
	B. One acre .	*Cephalostachyum pergracile* (Tinwa) .	448	2,993	338	50	42′-1″	6·6″	1,383·5	640·02	66·97	573·05	..	
	C. One acre .	*Ditto ditto* . .	387	2,938	535	50	39′-9″	6·5″	1,202·5	663·57	64·97	598·60	..	
		Average per acre of sample plots B and C.	**417·5**	**2,965·5**	**436·5**	**50**	**40′-11″**	**6·5″**	**1,293·0**	**651·79**	**65·97**	**585·82**	**39,871 or 18·77 tons**	
	D. One acre .	*Bambusa pallida* (Samidu-Wa) . .	1,112	5,411	282	100	39′-11″	6·2″	2,036·7	1,055·4	113·7	..	..	
Countings on 23rd September 1911.	A. One acre .	*Dendrocalamus Hamiltonii* . .	..	..	*47	..	..	..	..	..	..	..	..	*These are the number of new culms put out during the rains of 1911.
	B. One acre .	*Cephalostachyum pergracile* . .	..	..	*442	..	..	..	..	..	..	..	..	
	C.	*Ditto ditto* . . .	..	..	*384	..	..	..	..	..	..	..	..	
				Average .	413	..	..	..	..	..	..	..	..	
	D. One acre .	*Bambusa pallida*	..	..	*293	..	..	..	..	...	..	..	..	

NOTE.—He proposes to carry out further experiments by thinning the clumps, in order to ascertain the effect of cutting out mature culms on the growth of new shoots. The results of these experiments, when completed can be communicated, to any interested persons who care to make enquiries of the Forest Economist at Dehra Dun.

We are here chiefly concerned with the second species given in the above table, namely, *Cephalostachyum pergracile*, or Tinwa bamboos. The countings made in 1910 showed the two sample plots to contain an average of 417 clumps per acre, containing 2,965 old and 435 new culms, or a total of 8·1 culms per clump. It was found that 413 new shoots were put out by these clumps during the rains of 1911, that is 8·1 old culms were capable of producing, as nearly as possible, one new culm in one year. In Lower Burma countings made by the writer of the report (see Appendix I) gave one new culm to every 2·93 old ones, or roughly one new to every three old culms. The difference between the two results obtained is very marked, but nevertheless agrees in every respect with the mode of growth of bamboos. In the second paragraph of this section it has been explained how the culms and clumps as a whole increase in size, namely, that both the size of the stem produced and the number of culms put out in any given year depend on the power of the root-stock to store up nourishment against the period during which it has to produce new shoots.

Now the Tinwa bamboo clumps counted in Myitkyina Division by Mr. Buchanan were stated by him to be immature, while those counted in Lower Burma were somewhat over middle age, in other words, the root-stocks of the Myitkyina bamboos had not attained the same power of accumulating nourishment as had those in the areas inspected in Lower Burma and hence the difference in their relative power of producing new shoots every year.

In the foregoing paragraph, nothing has been said about the variation in climate in the two localities though, both areas, in which the countings were made, are typical bamboo areas for Upper and Lower Burma respectively. Without doubt the local conditions affect the growth of bamboos, so that the warm, damp, moist climate in Lower Burma no doubt partly accounts for the more favourable growth of *Cephalostachyum pergracile* in that locality.

4. Effect of cutting bamboos on the growth of the clump.

Effect of cutting stems on the growth of the clump.—The general impression arrived at after inspecting many areas in which fellings of bamboos have been carried on for many years, is that, in cases where a clump has been heavily cut over, the number of new stems put out is reduced according to the intensity of cutting, but that ultimately the

clump recovers, if given even only a short period of rest. And this is as might be expected, for the amount of nourishment which a clump can accumulate is governed by the leaf-area, so that when the leaf-area is reduced by felling a certain number of culms, the number of new shoots put out in the next season is correspondingly reduced. Another factor, however, comes into play when the vitality of a plant is reduced by cutting or pruning and that is that the plant struggles to regain its former normal state, so that with bamboos, which have enormous vitality, the deficiency is made up in a surprisingly short period of time.

Experiments on the cutting back of bamboos.—As a proof of the above assertion, there are to hand the records of experiments made some years ago in Burma, in connection with the extermination of bamboos to favour the growth of seedling teak.

The following is an extract from a letter on this subject from Mr. Muriel, Conservator of Forests, Pegu Circle, to the Chief Conservator of Forests, Burma :—

> "Experiments were made in the Tharrawaddy Division (new Zigôn and Tharrawaddy) from 1892 to 1897 to see if the cutting of the shoots of the year would cause the bamboo clumps to die * * *. An area of about 90 acres in the Kon Bilin Reserve of almost pure Kyathaung (*Bambusa polymorpha*) was operated over * * *
> An area of about 12 acres in the Bawbin Reserve of Kyathaung and Tinwa bamboo (*Cephalostachyum pergracile*) was similarly operated over * * * The experiment, as in the case of the Kon Bilin, being merely to determine the effect on the vitality of the bamboo clumps by cutting the annual shoots and *in both cases the experiment failed to have any appreciable effect on the vitality of the clumps.*"

In the above instance only the new shoots appear to have been cut. There is, however, to hand another experiment which was carried out in the Yaw Division, a copy of the report on which was sent by Mr. E. S. Carr, Conservator of Forests, to the Chief Conservator of Forests of Burma. The following extract is from the report by the Divisional Forest Officer, Yaw Division :—

> This work was incidental with the clearing of other undergrowth carried out in connection with an experiment, the

object of which was to determine the effect of cutting back bamboos over teak saplings (experimental plots Nos. 1 and 2, Lema, Gangaw Sub-division)."

"The following is taken from the Experimental Journal :—

March 1904. Forest Growth.

In both plots Myinwa (*Dendrocalamus strictus*) is plentiful occurring in clumps of about 20 to 40 stems and averaging 40 ft. in height.

Cultural operations.—Plot 1, practically cleared of bamboos and undergrowth."

"1904-05. Again completely cleared of undergrowth and bamboos."

"1905-06. *Inspection Notes.*—The effect of cutting back the bamboos has been to weaken it and out of each clump about one stem of 15 ft. high has been sent up.

"1906-07. *Inspection Notes.*—It is of interest that fresh culms arising from the old cut back clumps numbered from 4 to 5 stems per clump, as the result of two years' growth. They have been cut back again to facilitate getting about the area."

"1907-08. *Inspection Notes.*—It might be observed that most of this year's bamboo shoots in Plot 1, from the old stumps, have flowered."

"1908-09. *Inspection Notes.*—In Plot 1 the bamboo clumps cut down again have sent up one or two culms."

From the above records it is clear that even under the most drastic treatment, when the clumps are completely felled, several times in succession the old stock gradually recovers, and that it is practically impossible to completely destroy the plant in this way. It must, however, be recognised that the plant is weakened by over-felling and that to insure a sustained yield it must be given a period of rest between each successive felling.

5. Flowering of bamboos.

Flowering of bamboos.—The flowering of bamboos is a very complicated subject. The late Sir Dietrich Brandis, one of the greatest

experts on bamboos, divides them up into three classes when dealing with this question. The first group seeds yearly or nearly so and dies after flowering. With the species included in this group we are not concerned. The second he describes as flowering gregariously and periodically, all culms of one clump and all clumps in one district flowering simultaneously. He adds, however, that in different districts they flower at different times. In this case the culms die after ripening their seed, and usually the under-ground rhizomes also die. To this class belong *Bambusa polymorpha* (Kyathaung) and *Bambusa arundinacea*, two species with which we are closely concerned in the paper-pulp business. The third group contains irregularly flowering species, amongst which come *Cephalostachyum pergracile* (Tinwa).

Definite data as to the intervals at which the different species of bamboos flower are not yet available. Brandis states that *Bambusa polymorpha* flowers at long intervals, he records it as flowering in different localities in Burma in 1854, 1859, 1860, 1862 and 1871. Since then no general flowering has been recorded. *Bambusa arundinacea* of the West Coast and Peninsula is said to flower every 30 to 32 years, while *Cephalostachyum pergracile* (Tinwa) belongs to the third class, and is said by Brandis to flower frequently, at times gregariously over large areas. While on inspection in the Toungoo Division, an area of Tinwa which flowered in 1904 was seen ; many of the old dead culms were standing over a dense crop of young plants, six years after the flowering had taken place, and these old culms, though dry, appeared still suitable for pulping. *Melocanna bambusoides*, the last species with which we are concerned, flowers at long intervals. Brandis states that in Arakan it flowers every 30 to 35 years. The writer inspected certain areas which had flowered in various places in Arakan and he arrived at the conclusion that the bamboos flowered in large patches of several square miles on one hill-side, but found no instance of wholesale flowering all over one district or large catchment area.*

The question of the flowering of the bamboo and its subsequent drying is a factor that has to be seriously considered as affecting the sustained yield. There are, however, certain factors which make it possible to rely on a continued supply of raw material from the bamboo areas. The first is that generally more than one species occurs in every

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*NOTE.—It is understood that *B. arundinacea* has flowered heavily in certain localities of Kanara during the rains of 1911. Since the above was written the writer has noted nearly universal flowering of *M. bambusoides* in the Cachar Division of Assam.

forest and that the chances of them all flowering at the same time are very remote; secondly, that though the flowering may take place in one catchment area, or even over a whole district, at one time, the areas covered by bamboos are so vast that raw material will always be available from other localities, though the cost of extraction may be slightly increased for a time; and again dry culms do not disappear at once, so that the period during which the new crop is coming into existence may be partly tided over by extracting the dry culms to supply the mill; and lastly both *Bambusa polymorpha*, *Bambusa arundinacea** and *Melocanna bambusoides** only flower at long intervals.

6. Felling of bamboos.

Rotation on which to cut bamboos.—Bamboos have only been cut on a fixed rotation in places where the demand exceeds the supply. This is the case in the Lansdowne Division of the United Provinces, where the rotation is fixed at two and three years according to locality. We know nothing about the rotation for cutting *Bambusa polymorpha*, *Bambusa arundinacea*, *Cephalostachyum pergracile* and *Melocanna bambusoides* with which four species we are chiefly concerned.

On page 18 under the heading "Number of culms put out each year" it was stated that the proportion of new culms to old was as follows:—

	New.		Old.
Bambusa arundinacea	1	to	3·42
Bambusa polymorpha	1	to	4·22
Cephalostachyum pergracile	1	to	2·93
Average	1	to	3·52

The ratio therefore stands at 1 to 3·52, or say, as 1 to 4. It, therefore, requires four old culms to produce one new culm. Based on these figures, it takes four years to replace the old culms, leaving arithmetical progression out of the question. Now as the outturn from the areas dealt with in this report are capable of yielding annually a far greater quantity of material than any mill is likely to require for the present, the proposed rotation on which the sustained yield is based is put for

*NOTE.—It is understood that *B. arundinacea* has flowered heavily in certain localities of Kanara during the rains of 1911. Since the above was written the writer has noted nearly universal flowering of *M. bambusoides* in the Cachar Division of Assam.

safety's sake at five years. From experience it may be possible to reduce the rotation of felling for certain species of bamboos.

The rotation on which *Melocanna bambusoides* can be cut is put at 7 years, this figure having been arrived at by inspecting even-aged crops of this species in the Arakan Division.

Method of executing the cutting.—As has been shown above, it is not advisable to cut all the stems in one clump, as though by so doing the clump would probably not die, such drastic treatment would weaken it considerably. It is therefore proposed that 25 per cent. of the culms should be left per clump, of which at least half be young ones, to divide the area roughly into five blocks, and to carry out the cuttings in one block each year. Such an arrangement would not be possible were the total possible yield not far in excess of what is actually required. On the other hand, by such an arrangement the supply would certainly be maintained for ever.

After the cuttings have been carried out for one rotation and the effect of doing so ascertained, it might quite likely be found possible to modify the rules in the light of further experience. In any case, the Local Governments will, from the first, frame their own rules as regard the cuttings, which will be settled when a firm or company comes forward to apply for a concession, so that the above observations are only an outline of the possible solution to the problem.

Cutting stems of different ages.—As regards cutting stems of different ages, in practice it will be difficult to do more than differentiate between those under and over one year old.

In the past while carrying out laboratory tests, the experts have made fine distinctions between culms of 1, 2, 3, 4 years and over. As above stated, this is of no value in practice, as it is certain that while cutting bamboos on a large scale it will not be possible to make the coolies differentiate further than between under-and over-one-year old culms.

The effect on the growth of a clump by cutting under-one-year old culms is still a disputed point. It is generally recognised that they should be left standing. However, in the light of the experiments carried out in the Tharrawaddy and Yaw Divisions, and after inspecting a very large number of clumps over which fellings have taken place, it appears that the harm done to the clump is not so great as it is generally supposed to be. It is therefore thought that, provided about 50 per cent. of the new shoots are spared and that the cuttings are carried out

on a five-year rotation, there will be no harm done by cutting the other 50 per cent. of the new shoots.

7. Size and weight of bamboos.

Size and weight of culms of various species.—An important point is the size and weight of the culms of various species, as on these factors depends the facility and cost of their removal from the forest to the mill. Throughout this report the calculations of weights of dry bamboos and the yield per acre are based on the assumption that the nodes cannot be treated. This has been done for safety's sake, as by so doing the possible yield in tons from a given area is reduced and the cost increased. If, however, as demonstrated by the recent tests carried out on commercial lines at the Titaghur Paper Mills with chopped bamboos and by Raitt in his laboratory experiments with crushed bamboo, the nodes can be reduced to pulp (about which there is now no doubt), the estimates of yield per acre in this report may be raised 15 per cent. for *B. arundinacea*, 10 per cent. for *B. polymorpha* and *C. pergracile*, and 7 per cent. for *M. bambusoides*, while the cost of extraction may be reduced in proportion.

The following is the average size and weight of culms of the four species here dealt with :—

Species.	No. of culms on which the figures are based.	Average weight of one green culm, in lbs.	Average weight of one dry culm, in lbs.	Weight of dry inter-nodes yielded by one culm, in lbs.	Average length, in feet.	Average mid-girth, in inches.
Bambusa arundinacea .	1,084	62·0	42·0	35·7	44·3	8·9
Bambusa polymorpha .	400	35·96	Not known, as the nodes were cut out green.	20·05	43·6	9·3
Cephalostachyum pergracile.	400	15·08	Do.	9·82	33·05	6·05
Melocanna bambusoides	10,575	2·45	1·55	..	22·0	3·8

NOTE I.—The length of the culms was taken after cutting off the thin top where it was about one inch in girth, the figures being the average of culms cut in six districts of Bombay and Madras, four in Burma and one in Arakan.

NOTE II.—For full details on which the above figures are based, see Appendices I to VI.

NOTE III.—These figures are averages based on all countings made in various localities.

8. Cost of extraction.

Cost of extraction.—The cost of extraction must vary according to locality and species. In part IV of this report figures are worked out for each area dealt with; thus no general figure can be given. It will here be sufficient to summarise the various rates of cost in a table by showing the rates for each locality.

Cost of extracting bamboos in various localities in India and Burma.

Locality.	Species of bamboo.	Method of extraction.	Cost of extraction to mill, per 100 stems.	Cost of landing a ton of dry internodes at a mill.
BURMA.			Rs. a. p.	Rs. a. p.
(1) The Thonzé Reserve of the Tharrawaddy Division.	*Bambusa polymorpha.*	Floating .	4 0 0	5 12 9
	Cephalostachyum pergracile	Ditto .	2 8 0	7 6 0
(2) The Hlaing Yoma and Okkan Reserves of the Rangoon Division.	*Bambusa polymorpha.*	Ditto .	4 0 0	5 12 9
		By road and rail.	9 8 0	10 14 0
	Cephalostachyum pergracile.	Ditto .	3 0 0	8 13 7
			5 8 0	10 5 3
(3) Pyinmana Division	*Bambusa polymorpha.*	Floating .	7 8 0	6 8 5
	Cephalostachyum pergracile.	Ditto .	6 0 0	11 2 3
(4) The Bondaung, Kabaung, East Swa, and Saing Yané Reserves of the Toungoo Division.	*Bambusa polymorpha.*	Ditto .	6 8 0	5 10 6
	Cephalostachyum pergracile.	Ditto .	5 0 0	9 4 9
(5) The Seik Catchment area of the Arakan Division.	*Melocanna bambusoides.*	Ditto .	1 0 0	14 11 0

Cost of extracting bamboos in various localities in India and Burma—(concld.)

Locality.	Species of bamboo.	Method of extraction.	Cost of extraction to mill, per 100 stems.	Cost of landing a ton of dry internodes at a mill.
			Rs. a. p.	*Rs. a. p.*
(6) The Kaladan and Lemru Catchment areas in Arakan.	*Melocanna bambusoides.*	Floating .	1 8 0	21 12 0
BOMBAY.				
(1) The Gangavalli Catchment area in the West and East Kanara Forest Divisions.	*Bambusa arundinacea*	Ditto .	11 0 0	9 14 5
		By carting .	15 12 0	13 8 0
(2) The Kala Nadi Catchment area in the West and North Kanara Forest Divisions.	Ditto	Floating . .	10 0 0	9 0 0
(3) The Mungod Forests, of the East Kanara Forest Divisions.	Ditto	Carting to Bombanhalli;	8 7 0	8 6 0
		to Hubli.	16 6 9	13 1 0
MADRAS.				
(1) The Uppinangadi and Puttur bamboo areas in South Kanara Division.	*Bambusa arundinacea*	Carting and floating from Uppinangadi;	16 6 0	7 10 6
		ditto from Puttur.	23 12 0	11 13 0
(2) The Kanoth forest of the North Malabar Division.	Ditto	Carting . .	23 0 0	9 10 6
(3) The Nilambur and Amarampalam forests of the South Malabar Division.	Ditto	Floating: from Nilambur;	10 0 0	3 11 2
		ditto from Amarampalam.	15 0 0	5 8 10

NOTE.—In the event of it being found possible to pulp both nodes and internodes of any of the above species, the cost of landing one ton of dry internodes, as given in the last column, would be reduced from anything between 7 per cent. and 15 per cent. according to species.

The figures in the above table show variations from between Rs. 3 to Rs. 12 and in the case of the Kaladan and Lemru catchment areas Rs. 22 in the cost of extraction of one ton of dry internodes, and this is as might be expected, considering the varying conditions met with in the various provinces. The average is about Rs. 9 per ton for dry internodes and this figure is well within the economic limit of working, which is about Rs. 15 per ton.

A point which requires explanation is the relative cost of exploiting 100 bamboos as compared with the cost of landing one ton of dry internodes at the mill. Take, for instance, the Kanoth forests in Madras. It costs Rs. 23 to land 100 bamboos at the mill, while it only costs Rs. 9-10-6 to land a ton of dry internodes from the forest to that place. The reason for this is the enormous size to which the bamboos grow in that locality and therefore relatively few bamboos are required to make a ton of the raw material. The case is exactly the reverse in the Thonzé reserve of the Tharrawaddy Division, where 100 *Cephalostachyum pergracile* cost Rs. 2-8-0 only, but on account of their lightness it costs Rs. 7-6-0 to land a ton of dry internodes at the mill.

It is here of interest to note the figures of cost arrived at by Sindall in his report. In paragraph 31, page 13, of the report he writes: " Cost of bamboos for the manufacture of pulp, with bamboo costing Rs. 9-8-0 per ton, the value of the raw materials required for a ton of unbleached pulp works out at a reasonable figure."

From the above table of figures, which have been based on careful weighings of many stems, and on enquiries into the local conditions, the figure arrived at is generally lower than that quoted by Sindall; nevertheless, they correspond sufficiently closely to corrroborate that gentleman's estimates.

9. Outturn.

The outturn from any given locality must necessarily depend on the size of the area from which bamboos can be exploited and the size and density of the crop.

Valuation surveys in bamboo areas.—One of the most arduous portions of this enquiry has consisted in taking a very large number of sample plots and linear valuation surveys in the various areas which were inspected. In making these valuation surveys, after the sample plot had been laid out on the ground, every clump was counted within the area and every stem counted in each clump. In many cases the number of

stems was counted twice over so as to prevent any mistake being made. Further, while counting the number of stems in a clump, separate records were kept of the number of new and old culms. Another point kept in view was to always pick out areas where the growth of the bamboo was normal or slightly under normal. The results of these countings are given in detail in Appendices I to V.

Possible outturn from various localities.—These enumerations were made together with the weighings of green and dry culms, in order to ascertain the average yield per acre of dry internodes, so as to arrive at an estimate of the possible annual outturn of raw material in any given area. In the following table is given a résumé of the possible outturn for the various localities, which are described in detail in Part IV of this report:—

Locality.	Area from which bamboos can be exploited, in acres.	Species.	Approximate yield per acre, in tons.	Approximate annual sustained yield, working on a 5-year rotation, in tons.
BURMA.				
(1) The Thonzé Reserve of the Tharrawaddy Division.	40,037	*Bambusa polymorpha* and *Cephalostachyum pergracile.*	7·8	62,417
(2) The Hlaing Yoma and Okkan Reserves of the Rangoon Division.	86,700	Ditto .	7·8	135,305
(3) Pyinmana Division.	271,372	Ditto .	17·6	955,029
(4) The Kabaung, Bondaung, East Swa and Saing Yané Reserves of the Toungoo Division.	74,570	Ditto .	17·6	261,842
(5) The Seik Catchment area of the Arakan Division.	57,600	*Melocanna bambusoides.*	7·1	58,423*

*NOTE I.—Calculated on a 7-year rotation against 5 years for the other areas.

Locality.	Area from which bamboos can be exploited, in acres.	Species.	Approximate yield per acre, in tons.	Approximate annual sustained yield, working on a 5-year rotation, in tons.
BOMBAY.				
(1) The Gangavalli Catchment area in the West and East Kanara Forest Divisions.	1st class area 38,643 2nd class area 30,080 68,723	*Bambusa arundinacea.*	1st class area 5·3 2nd class area 0·88	40,321
(2) The Kala Nadi Catchment area in the West and North Kanara Forest Divisions.	Valley forests 20,374 Gund forests 7,000 27,374	Ditto .	Valley forests, 1st class, 5·3 2nd class 0·88 Gund forests 12·9	32,107
(3) The Mungod forests of the East Kanara Forest Divisions.	113,000	Ditto .	2·2	55,028
MADRAS.				
(1) The Uppinangadi and Puttur forest of the South Kanara Division.	35,798	Ditto .	2·9	17,051
(2) The Kanoth bamboo area of the North Malabar Division.	3,000	Ditto .	13·2	7,980
(3) The Nilambur and Amarampalam bamboo areas of the South Malabar Division.	9,380	Ditto .	10·9	17,676

PART III.

THE COST OF MANUFACTURING BAMBOO PAPER-PULP.

1. General remarks.

Points which required to be cleared up.—Up to the present day no firm has put up a mill in British India in which bamboos are utilized for manufacturing paper-pulp. It has been known, however, for many years that bamboos yield an excellent pulp, a point which has been repeatedly demonstrated by various experts in the laboratory. It is thought that the reasons why no steps have been taken up to the present to utilize bamboos for paper-making on a commercial scale, are that (*i*) persons interested in this subject entertain doubts as to the possibility of obtaining a continuous supply of raw material, at a reasonable price, (*ii*) that, without definite information as to a suitable locality from which to exploit bamboos they are not prepared to take up the subject seriously, (*iii*) that they cannot accept the figures of cost of manufacture based on data obtained in the laboratory only.

In Part IV is given detailed information, for stated localities, of the possible annual outturn and cost of extraction of bamboos which, it is hoped, will definitely clear up these points ; in this Part of the report it is proposed to deal with the last point, *i.e.*, cost of manufacture of bamboo-pulp.

Arrangements made for testing bamboos on a commercial scale.—In order to obtain, not an estimated but an actual figure of cost of manufacture, Messrs. F. W. Heilgers, Agents to the Titaghur Paper Mills, who were interested in this subject, addressed the Forest Research Institute in 1910, with a view to obtaining a large quantity of bamboos with which to carry out experiments on a commercial scale. The question of manufacturing pulp from bamboos being under enquiry by the Forest Economist at the time, an agreement was made with the firm to supply them with 20 tons of each of four different species of bamboo, on the understanding that the firm, in return, should give a report on the results obtained by them from their experiments. The results obtained by boiling the 80 tons of bamboos supplied to the firm will be dealt with hereafter.

2. Various processes by which the raw material may be converted into pulp.

Various processes for treating raw material.—There are four methods by which the raw material may be reduced to pulp, namely, by the sulphite, sulphate, and caustic soda processes and also by mechanical treatment. In connection with bamboo, the first process has been tried but bamboo sulphite pulp is extremely difficult to bleach, which renders the process unworkable on a commercial scale. The preparation of mechanical bamboo-pulp, so far as is known, has never been attempted and it is highly improbable that it could ever be prepared in this way. We are therefore only concerned with the sulphate and caustic soda processes. The former has been tried on a laboratory scale by Raitt, and he has obtained slightly better results by this process than those obtained with caustic soda. The results of his work are fully described in his report published in the Indian Forest Records, Volume III, Part III, entitled—" Report on the Investigation of Bamboo as material for Production of Paper-pulp." Whether the results obtained by the sulphate process in a mill will be equal to those obtained with caustic soda and whether the resultant half stuff will prove to be of equal quality, remains to be proved.

3. Species of bamboos for paper-making.

Species of bamboos.—The question of the species of bamboo useful for paper-making has been discussed elsewhere. It is not only a question of the suitability of any given species for the manufacture of pulp but also largely a consideration of the available supply in large quantities, etc., at cheap rates and from suitable localities. The four species dealt with in this report are :—

(1) *Bambusa polymorpha* (Kyathaung).
(2) *Cephalostachyum pergracile* (Tinwa).
(3) *Bambusa arundinacea* (Daugi).
(4) *Melócanna bambusoides* (Muli).

It is with these four species of bamboos that tests have been carried out on a commercial scale.

4. Preparation of the bamboo before treatment.

Nodes and Internodes.—A difficult point to settle was the vexed question of how to deal with the nodes or joints of the bamboo.

Experts up to recent times have been of opinion that the nodes and internodes could not be treated together, and at the time the writer first took up the enquiry, he was of the same opinion. Had it been known from the first that in the case of *B. polymorpha*, and *C. pergracile* both nodes and internodes could be treated together, much labour and time might have been saved. When inspecting the various bamboo areas and at the time of counting and weighing large quantities of bamboos to obtain figures of outturn per acre, the bamboos which were cut for this purpose were further cut into tubes and the nodes and internodes weighed separately. The results obtained are given in the Appendices, and throughout the report mention is made both of the nodes and internodes. To obtain the total weight of the bamboos it is only necessary to add the weight of nodes to that of the internodes, while in the case of B. *arundinacea* and possibly in that of *M. bambusoides* it will be necessary to cut out the nodes before treatment, so that the calculations, based on the internodes only, have been left as they are in the report.

Crushing versus *cutting bamboos before treatment.*—To overcome the difficulty of treating nodes and internodes together, Raitt, in his above-quoted report, advocates crushing the bamboos between rollers and in this way proposes to reduce the material to a tow-like substance. This method has its advantages and disadvantages. The liquor acts more readily on the crushed material resulting in more rapid liberation of the fibre; on the other hand, the material is rendered more bulky and the capacity of a digester is reduced by one-half.* The other method is to chop the material into narrow sections about 1″ long. The results obtained, by treating both nodes and internodes of B.*polymorpha* and *C. pergracile* bamboos, by cutting them into short sections and boiling them in large digesters, have proved most successful.

Washing bamboos before boiling.—Owing to the dust and dirt which is found in bamboos, especially those which have been stored for a considerable time, it has been found necessary to first pass the cut chips through a fanning machine and afterwards to wash them in running water.

Steaming.—Raitt, in his report, advocates treating the bamboos by steaming or boiling them in water before introducing the liquor.

* NOTE.—Since writing the above Raitt has been able to reduce the bulk of the raw material when crushed by a process of fractional distillation.

This is a most important point and one, which it is necessary to carry out, in order to reduce the amount of starch before introducing the liquor, otherwise the percentage of caustic soda required to reduce the raw material to pulp is considerably increased. A period of two hours boiling in water is thought to be sufficient, after which it may be run off and the caustic liquor introduced.

5. Results of boiling bamboos on a commercial scale.

B. polymorpha, " Kyathaung " *bamboos.*—In order to give a correct idea of the results obtained by boiling bamboos on a commercial scale it will be necessary to quote from the report received from the Titaghur Paper Mills. They write as follows :—

> " Our best results with *B. polymorpha* bamboos have been got with our special high pressure digester, which has been recently brought into use. So far we have been able to reduce our caustic to 18 per cent. and bleach quite up to our Government standard with 10 per cent. of 35 per cent. bleaching powder. Time under pressure was one hour at 110 lbs. and five hours at 80 lbs. per square inch. Our yield of pulp showed 46 per cent., caustic and bleach are calculated on the weight of air-dry bamboo. We are handicapped at present for want of a suitable cutter for the bamboo. This will be rectified at an early date, when we hope to still further modify our caustic and bleach."

C. pergracile " Tinwa " *bamboo.*—The following is their report on the trials made with this species :—

" Our trial boils with this species were made in our ordinary fibre digesters, at a pressure of 60 lbs. per square inch. The fibre was boiled with 23 per cent. of 77 per cent. caustic for ten hours. The pulp required 15 per cent. of 35 per cent. bleaching powder to bring it up to our standard of whiteness for Government printing paper. The yield in paper showed 40 per cent. caustic and bleach calculated on air-dry weight of raw material. Several boils were put through on similar lines with variations in time, caustic and pressure but the pulp obtained, under the above conditions, was probably the best of the boils."

They go on to state : "the *C. pergracile* or Tinwa sample lot was all used up in trials at the lower pressure of 60 lbs., but we have no doubt it will give equally good results with *B. polymorpha* under similar treatment."

B. arundinacea, "Daugi" *bamboos.*—Their report on this species runs as follows :—

"This species we boiled for twelve hours with 24 per cent. of caustic and it came out much under-digested. This bamboo is a failure so far as our experiments have gone, but this does not mean that the species is useless for paper-pulp, but that further investigation is necessary, in order to find out the proper method of treatment."

B. arundinacea is an extremely heavy species, with thick walls and heavy nodes, it is very probable that Raitt's method of crushing will have to be resorted to in order to treat this species, and possibly it may also be found necessary to cut out the nodes.

M. bambusoides, "Muli" *bamboos.*—The report on this species runs as follows :—

"We treated this species exactly as in the case of *B. polymorpha,* but the fibre was not fit to make white paper. It gave a good looking pulp, but it would not bleach with a reasonable quantity of bleaching powder. Also small black stringy fibres appeared throughout the pulp, which are most objectionable, as they cannot easily be taken out and would spoil white paper, even if the bleaching difficulty were got over."

It is evident that *Melocanna bambusoides* bamboo will require further testing, before it can be used for paper-pulp.* The question of producing a better colour by bleaching, within economic limits of working, may possibly be overcome by treating this species by the sulphate process. The appearance of dark stringy fibre in the pulp may very likely be due to the black fibre in the nodes, or in the sheath in which case it will be necessary to cut out the joints or get rid of any adherent portions of the sheath.†

6. Cost of manufacturing one ton of air-dried unbleached pulp.

The whole question of manufacturing bamboo-pulp at a profit, that is to say, a pulp capable of being converted into high class printing

* NOTE.—Further tests with this species of bamboo have been arranged for, the bamboos for testing being sent from Arakan.

† NOTE.—It has been ascertained, since writing the above, that the sheath is the cause of the black stringy fibres, and these can easily be cut off before treatment.

paper, depends on the cost of production. Taking the figures arrived at by boiling *Bambusa polymorpha* or Kyathaung bamboo on a commercial scale and the cost of the raw material as given in Part IV, we arrive at the following figures of cost for manufacturing unbleached bamboo-pulp in or near Calcutta.

Calculation based on a 46 per cent. yield on weight of air-dried material obtained by boiling with 18 per cent. caustic.

1. The amount of raw material required to make one ton of air-dried pulp is 2·17 tons. The cost of one ton of air-dried bamboo in Rangoon may, on an average, be said to be Rs. 10 (see Part IV), therefore the cost of 2·17 tons works out at Rs. 21-11-0. Freight from Rangoon to Calcutta Rs. 7 per ton or Rs. 15-3-0 for 2·17 tons. Total cost of raw material, to produce one ton of unbleached pulp in Calcutta, therefore, works out at Rs. 36-14-0.

2. It requires 18 per cent. of caustic soda to reduce 2·17 tons of raw material to one ton of pulp or a total of 7·8 cwts., say, 8 cwts. at Rs. 6 per cwt. of fresh and recovered caustic works out at Rs. 48.

3. Cost of coal, of which $1\frac{1}{2}$ tons are required to produce one ton of pulp, at Rs. 9 per ton = Rs. 13-8-0.

4. Labour, superintendence, Rs. 10.

5. Fixed charges, depreciation, repairs, etc., Rs. 10.

Abstract.

	Rs.	A.	P.
Raw material	36	14	0
Chemicals	48	0	0
Coal	13	8	0
Labour	10	0	0
Fixed charges	10	0	0
TOTAL .	118	6	0

Were the pulp to be manufactured in Rangoon, the cost of the raw material would be reduced by Rs. 15-3-0 while the cost of the coal would be increased by Rs. 6-8-0, so that the cost of unbleached pulp in Rangoon works out at Rs. 109-11-0.

Comparing the cost of other unbleached paper-pulp in Calcutta we obtain the following figures :—

Unbleached *Sabai* grass soda pulp, per ton	Unbleached *spruce* sulphite pulp, per ton	Unbleached *bamboo* soda pulp, per ton
Rs. A. P.	Rs. A. P.	Rs. A. P.
162 2 0	150 0 0* to 155 0 0	118 6 0

In calculating the cost of manufacturing bamboo-pulp, various estimates have been put up by experts, based on their laboratory experiments. Raitt, in his report, estimates Rs. 92-8-0 as the cost of preparing unbleached sulphate bamboo-pulp. These figures are for unbleached bamboo-pulp near Rangoon. His figures differ from the above figures in that his chemicals cost Rs. 29-14-0, as against Rs. 48-0-0 in the above estimate, otherwise they are more or less in agreement.† Sindall, on page 43 of his report entitled "Bamboo for paper-making," 1909, estimates the cost of manufacturing bamboo unbleached pulp at £5-10-0, a most optimistic figure.

In arriving at the figure of Rs. 118-6-0 for unbleached bamboo-pulp in Calcutta, it will be seen that all items have been somewhat liberally estimated, probably when extracting bamboos on a large scale it will be found possible to do so for less than Rs. 10 per ton, while the sum fixed for labour and fixed charges, Rs. 20 in all, is a higher figure than that generally adopted by experts.

In spite of the liberal estimate given, the total cost of producing unbleached *bamboo*-pulp works out at Rs. 32 per ton lower than that for imported unbleached *spruce*-sulphite and Rs. 24 per ton lower than the cost of producing unbleached *Sabai* grass-pulp.

* NOTE—This figure includes the manufaturer's profits, while the figures given for Bamboo and Sabai grass soda pulp do not include his profits.

† NOTE.—The reason for the difference in cost of chemicals is that the amount of recovery, as accepted in this report, is based on that obtained when working with grass, whereas Raitt maintains that greater recovery can be expected from Bamboo. His contention is no doubt correct, but until more reliable data are forthcoming on this point it is safer for the present to adopt the higher figure.

PART IV.

DETAILED REPORTS ON THE VARIOUS BAMBOO AREAS IN BURMA AND INDIA.

POSSIBLE SITES FOR BAMBOO PAPER-PULP MILLS IN BURMA.

Burma Area No. I. (*See portion marked* **A** *on map.*)

The Thonzé Reserve of the Tharrawaddy Division.

(1) *Name and Situation.*

The forests with which this scheme is concerned are situated in the catchment area of the River Thonzé, which drains a portion of the western slopes of the Pegu Yoma in the Tharrawaddy Division. This river finds its source in the main ridge of the Yomas and follows a winding course south-westwards, through the lower hills of the range until it emerges into the plains at Wéywa. Thence it passes between deep banks to the village of Thonzé, where it cuts the railway, and eventually six miles lower down flows into the Myitmaka at Sanywé. (See map.)

This area, which has been chosen as a possible locality from which bamboos might be exploited to supply a pulp-mill, lies to the north of the Okkan Reserve of the Rangoon Division, which is dealt with hereafter, and is a continuation of those forests, though lying in a different catchment area. Again, to the north of this area, lies the Kadin Bilin reserve, drained by the Bilin River, and also a continuation of the same block of forest, which stretches northwards from the Okkan river along the western slopes of the Pegu Yoma for a distance of many hundreds of miles.

(2) *Description of the forests.*

The area is, for the most part, covered with dry deciduous teak, pyinkado and bamboo forests, with patches of evergreen in the moister localities, a large number of teak plantations near the western boundary and 8,000 acres of inferior forests, ceded to the Karens, in which to practise shifting cultivation. By far the greater portion of the area is fully stocked with bamboos of four or five different species, and only in

some of the plantations, evergreen and Karan areas, are they in any way scarce. These forests and those of the Okkan which are described hereafter, resemble each other, especially as regards the growth of bamboos.

(3) *Area of the forest covered with bamboos.*

The total area of the forests situated in the catchment area of the Thonzé River is 69,734 acres, which is made up as follows :—

1. Area from which bamboos can be exploited	40,037 acres.
2. Evergreen forest	8,000 "
3. Karen area in which shifting cultivation is practised . . .	8,200 "
4. Area containing bamboos but from which exploitation is difficult	13,497 "
TOTAL .	69,734 acres.

The area, therefore, with which we are concerned is 40,037 acres, from which bamboos can be exploited without difficulty. It may here be mentioned that, out of the 13,497 acres in which bamboos occur, but from which exploitation is difficult, 4,565 acres are situated above the waterfall on the Kodugwé tributary and 8,932 acres are situated on the steep slopes of the main ridge of the Yomas, whence extraction would be difficult and costly.

(4) *Species of bamboos and mode of growth.*

The prevailing species in these forests are *Cephalostachyum pergracile* (Tinwa) and *Bambusa polymorpha* (Kyathaung); *Dendrocalamus strictus* (Myin) is common on the ridges and *Teinostachyum Helferi* (Wathabut) along the streams and in the evergreens. From Appendix I it will be seen that the average length of 200 cut stems of Tinwa is 28 feet and mid-girth 5·7″, while an equal number of Kyathaung average 33 feet and 8·8″ mid-girth. An important point in the growth of bamboos is the number of new stems put out yearly as compared with the number of old stems in the clump. From Appendix I we find that the average number of Tinwa stems per clump is about 9 of which 23 per cent. are new and 77 per cent. old, or in round figures as 1 is to 3. In the case of Kyathaung the number of new stems is proportionally greater. The figures show roughly 11 stems per clump, of which 30 per cent. are new and 70 per cent. old, or as 1 is to $2\frac{1}{3}$.

(5) *Possible factory sites.*

There are two possible factory sites. One is where the Thonzé river cuts the railway at the village of Thonzé, two miles south of Tharrawaddy railway station (see map), the other is near Insein on the Hlaing or Myitmaka river. Were the latter site to be chosen, the Thonzé and Okkan bamboo areas could be worked together. The advantages of the latter site will be fully described under this head in the Okkan scheme. (See page 48, section 5.)

The first suggestion is to have a mill at or near the village of Thonzé, on the banks of the river. Such a place has distinct advantages. It is on the railway and also near a good perennial stream of water. It is 12 miles by river from the edge of the bamboo area at Wéywa and 20 miles from the centre of the forests. From Thonzé, to the junction of the river with the Myitmaka at Sangwé, is 6 miles and along this stretch of river small boats loaded with 2,500 to, 3,000 lbs. of rice ply without difficulty. From the junction of the rivers at Sangwé boats carrying 10—12,000 lbs. of rice go down to Rangoon. It might be thought advisable to place the factory at Sangwé, but this is not practicable, as the river overflows its banks in the monsoon, a circumstance which would practically stop all work during those months and possibly damage the mill.

(6) *Outturn.*

As will be done when calculating the outturn from the Okkan and Hlaing Yoma Reserves, the figures of yield for this reserve are based on the average outturn per acre of all the sample plots situated in the two bamboo areas, namely, those of the Thonzé and Okkan Reserves. This has been done in order to obtain a more reliable figure, as the forests of both divisions are of the same type as far as bamboos are concerned.

The area of the bamboo-yielding forests in the Thonzé Reserve has been shown as 40,037 acres. From Appendix I it will be seen that an acre yields 8,254 lbs. of dry internodes of *Cephalostachyum pergracile* (Tinwa) and 9,255 lbs. of dry internodes of *Bambusa polymorpha* (Kyathaung). Thus the gross yield of pulpable material works out at 312,288 tons, or, working on a 5-year rotation, the sustained yield of dry internodes comes to 62,417 tons per annum.

Were the Kadin Bilin catchment area, which lies directly north of the Thonzé Reserve and which is a continuation of the same block of forests, to be worked in addition, the outturn could be nearly doubled.

The export of bamboos from the Thonzé Reserve is already considerable. The bamboos are floated down the river, some are sold locally in Tharrawaddy, but the greater number are taken on down the Myitmaka to Rangoon. The outturn of all species of bamboos during the last five years was as follows :—

Year.	Number.
1905-06	629,100
1906-07	546,550
1907-08	497,000
1908-09	494,700
1909-10	503,500
Average .	534,170

(7) *Lines of export.*

The bamboos are at present dragged to the main or by-streams, a distance of under a mile. They are then rafted down the main stream from 15th May to the end of November. After November and up to February, rafts can still be taken down, but they require to be pushed in places, thus rendering the cost of extraction higher. Floating is carried on down the by-streams from the commencement of the monsoon until October. The greatest distance over which floating is necessary, namely, from the foot of the main ridge of the Pegu Yoma at Kaingdagyi to Thonzé, is 32 miles. A waterfall exists on the Kodugwé, on one of the largest northern tributaries, at a distance of 7 miles from its junction with the main stream. Floating is, therefore, not possible above this point, and in estimating the area of bamboo forest, the compartments above the waterfall have been excluded from the calculation.

Once the bamboos are in the main stream no difficulties occur in floating them down to the village of Thonzé or on to Rangoon.

The question was once raised by a District Forest Officer whether by floating large quantities of bamboos down this river the floating of the teak logs, annually exported from these forests, would not be interrupted. Careful enquiry was made on this point and the present District Forest Officer and also some of his subordinates, who have been working for many years in this locality, apprehend no difficulties.

The present method by which bamboos are extracted, is to make rafts of three sections, each containing 300 Kyathaung or 600 Tinwa bamboos ; these are floated down the upper reaches in charge of one man. As the stream widens out, the rafts are increased in size and on reaching the Myitmaka or Hlaing river, several sections are tied side by side and rafted down in lots of 6,000 to 7,000 to Rangoon.

(8) *Cost of cutting and extraction.*

The present rates for selected straight Tinwa bamboos, 20 feet in length, at Thonzé on the railway line, is Rs. 3 to Rs. 5 per 100 stems and for Kyathaung Rs. 6 per 100 and for fine selected stems Rs. 8 per 100. This includes royalty and contractor's profit. The figure of cost of extraction of bamboos on a large scale of both species, taking crooked and straight stems together, is put at Rs. 3 per 100 by the Divisional Forest Officer. This includes profits to the contractor but not royalty charges. Were the Rangoon supply to clash with that of a pulp-mill, it is possible that the price might go up 25 per cent. A safe figure on which to base the cost of extraction will, therefore, be Rs. 2-8 per 100 stems of Tinwa, and Rs. 4 per 100 stems of Kyathaung.

(9) *Cost of landing dry internodes per ton at the factory site.*

Supposing Thonzé to be selected as a mill site, the cost of landing dry internodes at the factory will be as follows :—

(*i*) *Cephalostachyum pergracile* (Tinwa).—The weight of dry internodes yielded by one Tinwa is 7·6 lbs. (See Appendix I), and it requires 295 stems to yield one ton of dry internodes. Therefore the cost of extracting 295 stems or, in other words, of landing one ton of dry internodes at Thonzé at Rs. 2-8 per 100 comes to Rs. 7-6-0 per ton.

(*ii*) *Bambusa polymorpha* (Kyathaung).—The weight of dry internodes yielded by one Kyathaung is 15·4 lbs. (see Appendix I), and it requires 145 stems to yield one ton of dry internodes. Therefore the cost of extracting 145 stems or, in other words, of landing one ton of dry internodes at Thonzé, at Rs. 4 per 100, comes to Rs. 5-12-9 per ton.

(10) *Labour.*

A certain amount of local labour is available. It is said that 12 villages situated on the Thonzé and lying between the forest and the Railway could supply 300 to 400 coolies from June to November, but that in December the number would be reduced, owing to the commencement of rice harvest. On the other hand, were a mill to be started in these parts, it is probable that a far larger number of coolies would be forthcoming, once it became known that regular labour was obtainable on piece-work.

Turning now to the amount of work a man can do, it is known from experience that a good labourer can extract about 5,000 Kyathaung stems between June and November, so that 400 men could work out 2,000,000 stems in that time. Taking one stem as yielding roughly 15 lbs. of dry Kyathaung internodes, 400 men would extract 30 million lbs. or about 13,400 tons in the six months. The above figures make no allowance for loss in transit, so that 12,000 tons would be a safer figure to quote, and this amount would not be sufficient to supply a large mill. Under the circumstances it would be necessary to import labour, either from the neighbouring districts or from India, as is done to harvest the rice crop.

There would be no difficulty in procuring contractors who would undertake to exploit the bamboos.

The official rate for labour is 8 annas a day, though probably 9 annas would have to be given. It is said that a good workman can earn Re. 1 per day during the harvest season.

(11) *Firewood.*

About 100,000 c.ft. stacked firewood is annually available from the Plains Forests. Supposing the fuel supply required for a mill to be greater than the above amount, a rough working-plan could be prepared for the Théwa and Kauni Fuel Reserves, and the coupes so arranged that a sustained annual yield could be procured. To do this arrangement would have to be made in advance.

The price of fuel at Tharrawaddy is Rs. 2-6-0 per 100 c. ft. stacked and at Thonzé Rs. 2-12-10.

(12) *Chemicals.*

No lime is available in the vicinity of Thonzé, so that it would have to be procured from Rangoon, where the price is about 5 annas per cubic foot. Excellent lime is also available in large quantities from Moulmein. All the other chemicals necessary would have to be imported to Rangoon by sea, and taken up the Rangoon river to the factory site.

(13) *Miscellaneous facts.*

The proposed factory site is situated in the plains and is surrounded by cultivation, chiefly rice. It is not an unhealthy spot, is well situated on a fair river and close to the railway. It is just possible that a more satisfactory site could be found lower down the river, nearer Rangoon and somewhere above tidal level. The forests are not unhealthy, except after the monsoon, when fever is prevalent.

Burma Area No. II. (*See portions marked* ***B*** *on map.*)

The Hlaing Yoma and Okkan Reserves of the Rangoon Division.

(1) *Name and Situation.*

These forests lie in the Rangoon Division and are known as the Okkan and Hlaing Yoma Reserves. They are situated on the western slopes of the southern extremity of the Pegu Yoma and therefore lie to the east of the Irrawaddy river. In this locality the Pegu Yoma forms a range of broken hills rising to 800 feet with considerably higher points along the main ridge. They are drained by numerous small streams which find their way into the larger feeders of the Hlaing, the most important of which is the Okkan river, which flows through the central and northern portion of the area. (See map.)

(2) *Description of the forests.*

To the east of Palôn Railway Station occur what are known as the Plains Forests, in which extensive teak plantations exist, and in which comparatively few bamboos occur. About 8 miles east of the railway commences the broken hilly ground of the Yomas covered with

moist-deciduous forests, containing teak and other species, with continuous bamboo forests up to the top of the western watershed, which constitutes the boundary of the Pegu Division. This type of heavy teak and bamboo forest with small modifications, occurs all over the hill ranges, passing northwards through the Okkan Reserves into the Tharrawaddy Division.

(3) *Area of forests covered with bamboos.*

The above-mentioned Plains Forests, which constitute the North and South Hlaing Reserves, have been eliminated from this scheme, as they contain relatively few bamboos. The areas taken into consideration are those which comprise the forests situated on the hilly ground in front of the main ridge of the Yomas and which go to make up the western watershed of the main range. For the sake of convenience, the area has been divided into two parts, according to the lines of export available, though both reserves form one continuous block of forest :—

Name of reserve.	Compartment Nos.	Area in acres.
Hlaing Yoma Reserve	9 and 13 to 28	26,701
Okkan Yoma Reserve	29 to 100	81,663
	TOTAL .	108,364

(4) *Species of bamboo and mode of growth.*

The prevailing species are *Cephalostachyum pergracile* (Tinwa) and *Bambusa polymorpha* (Kyathaung) which together make up about 80 per cent. of the bamboo growth. *Dendrocalamus strictus* (Myin) occurs on the ridges, and is often found growing on poor soil, but, for reasons stated elsewhere, this species has not been included in the scheme. Besides the above bamboos, a creeping species occurs, known as *Teinostachyum Helferi* (Wathabut) and a bamboo named *Dendrocalamus longispathus* (Waya).

The two first-named species, Tinwa and Kyathaung, are very abundant. The former is a comparatively small unarmed bamboo, with an average stem of 6″ to 7″ mid-girth and cutting into lengths of 25 to 30 feet. It yields a fairly strong stem, but not thick-walled, and is easily cut and extracted. The latter is a larger unarmed bamboo, with

a mid-girth of 8″ to 9″ and cutting into lengths of 30 to 40 feet. It is thin-walled, with small nodes from 18″ to 29″ apart and is by no means difficult to extract. Both the above-mentioned species are softer and lighter bamboos than the prevailing species of the West Coast (*Bambusa arundinacea*) and being unarmed are therefore more easy to fell and extract. (For average size and weight of these species see Appendix I.)

(5) *Possible factory site.*

There are two possible ways of dealing with this scheme. The first is to locate the pulp-mill on the Okkan river, near to the point where the river cuts the Rangoon-Prome Railway, that is, 2 or 3 miles north of Okkan Railway Station and 13 miles from the outer boundary of the Okkan Reserve. The alternative proposal is to have a mill below the junction of the Okkan and Hlaing, otherwise known as the Myitmaka river, or in the event of no suitable site being found there owing to danger from floods, further down the stream at or near Insein, which is 10 miles above Rangoon. If the first site were adopted the supply of raw material would be confined to the Okkan and Hlaing Yoma Reserves, which are themselves capable of supplying sufficient bamboos to work a large paper-pulp mill. On the other hand, were the mill placed at Insein on the Hlaing river, of which the Thonzé as well as the Okkan are tributaries, the former draining a bamboo area to the north of the latter river, and fully described above, it would be supplied from two separate bamboo areas, and at the same time would be sufficiently far down the river to allow of large boats coming up from Rangoon. The respective merits of these two sites can only be compared after the capacity of the mill has been definitely determined. In fixing the site it would be of the first importance to consider the advantage of having two areas from which supplies of raw material would be available ; the question of having a greater area over which to recruit labour ; and the proximity and connection by water with Rangoon, as against concentration of labour and the proportionate reduction in establishment were the bamboos procured from one reserve only. As regards the water supply, there is always a sufficient quantity flowing down the Okkan and Hlaing rivers to meet the requirements of a factory at either place. These remarks apply with equal force to the scheme for the Thonzé Reserve described above.

(6) *Outturn.*

A considerable number of bamboos are extracted annually from the Okkan Reserve, the figures for the last five years being as follows :—

Year.	No. of bamboos.
1905-06	548,600
1906-07	487,100
1907-08	660,000
1908-09	700,000
1909-10	610,000
Average	601,140

So as to obtain a more reliable figure of outturn, based on the enumerations and weighings carried out in the various bamboo sample plots, it has been decided to take the figures obtained not only from countings in the Hlaing Yoma and Okkan Reserves of the Rangoon Division, but also those obtained from the sample plots in the Thonzé Reserve of the Tharrawaddy Division. Though these three reserves lie in two different Divisions for administrative purposes, they form one continuous belt of forests in the Pegu Yoma, in which the species and mode of growth of the bamboos is for all purposes the same.

The combined bamboo area of the Hlaing Yoma and Okkan Reserves is 108,364 acres. Portions of these areas contain no bamboos, such as Taungya areas, roads, river beds, and scarps, while areas also exist from which the extraction of bamboos would be too difficult and costly, so that, for safety's sake, we may reduce it by 20 per cent. leaving 86,700 acres of productive bamboo forest to be dealt with. From Appendix I it will be seen that the forest can yield 8,254 lbs. of dry internodes of *Cephalostachyum pergracile* (Tinwa) and 9,255 lbs. of dry internodes of *Bambusa polymorpha* (Kyathaung) per acre, or a total of 17,509 lbs. or 7·81 tons per acre. Thus the gross yield of pulpable material works out at 676,527 tons or, working on a 5-year rotation, the sustained yield of dry internodes comes to 135,305 tons per annum.

(7) *Lines of export.*

In forming an estimate of the cost of extraction and the methods by which the bamboos could be exploited, the propósed factory site is taken to be on the Okkan river, somewhere near to the point where that river cuts the railway. (See red circle on map.) However, were the factory to be erected near Insein on the Hlaing, otherwise known as the Myitmaka river, the extra expense incurred in floating the bamboos another 30 miles or so down from the Okkan railway bridge would be relatively small.

The Okkan river, with its tributaries, of which the more important are the Yindaik, Kangya, Chaungyaung and Mingaung, completely taps the Okkan Reserve, while the main stream passes the proposed factory site at Okkan village. It is not a large river, being about 50 yards broad where it comes out of the reserved forest, and its bed is sandy, with few boulders to impede floating. It is the main stream by which bamboo rafts are brought down to the railway from the Okkan forests. These rafts, of which several were being taken down when the river was inspected, are constructed in the upper reaches of the river and floated down any time from the middle of June to the middle of January. In the smaller tributaries floating is not possible after October. After the bamboos have been dragged to the main or by-streams, a distance of one mile or less, they can be floated directly from the forest to the factory, the distance from the centre of the Reserve to that place being about 18 miles.

The work of extracting bamboos from the Hlaing Yoma Reserve is of a somewhat different nature. From Compartments 9 and 13 to 25 the bamboos can be dragged and carted to Thanachaung Railway Station (see map), an average distance of 8 miles, and from there they can be railed to the factory near Okkan station, a distance of about 15 miles, while Compartments 26 to 28 and 29 to 30 can be worked out by dragging for a mile or so and carting 7 miles to Palôn station, whence they can be taken by rail some 10 miles to the factory. The lines of export are therefore very suitable for the extraction of bamboos, for when the supply of raw material from the Okkan Reserve is no longer available, owing to insufficient water in the river for floating operations, *i.e.*, during six months in the year, it will be possible, owing to the fair weather roads being open to cart traffic during the dry season, to exploit bamboos from the Hlaing Yoma Reserve, thus ensuring a continuous supply of raw material throughout the year.

(8) *Cost of cutting and extraction.*

The cost of cutting 100 *Cephalostachyum pergracile* (Tinwa) bamboos, dragging them to a by-stream and floating them to the edge of the reserved forest, for instance to the village of Shawbon, comes to Rs. 2, and for *Bambusa polymorpha* (Kyathaung) Rs. 3 per 100. The cost of making them up into rafts and taking them down to the factory site will come to Re. 1 per 100, or a total cost of Rs. 3 per 100 for Tinwa and Rs. 4 per 100 for Kyathaung. The royalty on bamboos is annas 5 per 100, while Tinwa bamboos, 20 feet long, sell at present in the Okkan market for Rs. 4 to Rs. 6 per 100 and Kyathaung, Rs. 5 to Rs. 7 per 100, according to quality.

For the Hlaing Yoma Reserve the estimates are as follows : Cost of cutting and dragging to a cart-road, Rs. 2 per 100 for Tinwa and Rs.3 per 100 for Kyathaung. Carting costs 3 annas per mile, and the average distance of the forest from the Railway is 8 miles, or Re. 1-8 per cart. A cart can take 100 Tinwa or 33 Kyathaung, so that the total cost of landing Tinwa on the station works out to Rs. 3-8 and for Kyathaung Rs. 7-8, per 100. To these estimates must be added the cost of loading and railing the stuff some 15 miles to Okkan, say Rs. 2 per 100, which raises the total cost to Rs. 5-8 and Rs. 9-8 per 100, respectively.

(9) *Cost of landing dry internodes per ton at the factory site.*

The weight of dry internodes yielded by one average Tinwa bamboo is 7·6 lbs. and that by a Kyathaung 15·4 lbs. (see Appendix I), therefore it takes about 295 Tinwa or 145 Kyathaung to yield a ton of dry internodes. The cost of landing the bamboos from the Okkan Reserve at the proposed factory site is Rs. 3 and Rs. 4 per 100 respectively, so that the cost of landing dry internodes of Tinwa at the mill works out to Rs. 8-13-7 per ton and of Kyathaung at Rs. 5-12-9 per ton.

The cost of landing bamboos from the Hlaing Yoma Reserve is Rs. 3-8-0 and Rs. 7-8-0 per 100 respectively, so that the cost of landing dry internodes of Tinwa at the mill works out to Rs. 10-5-3 per ton and of Kyathaung at Rs. 10-14-0 per ton. Were the site of the mill fixed at Insein, 8 annas would have to be added to the cost per ton. In the event of the nodes being utilised, the average cost of Tinwa and Kyathaung together works out to Rs. 10 per ton in round figures, and this is the figure taken by Raitt for his estimates.

(10) *Labour.*

Local labour cannot be relied upon at all To begin with it is scarce and only obtainable in limited quantities after the rice crop has been reaped. A Burma cooly can earn 9 annas to Re. 1 per day according to the nature of the work on which he is employed. Cooly labour from India is obtainable at Rs. 12-0-0 per month, and is extensively employed and with advantage by the Forest Department for work such as clearing fire-lines. It will certainly be necessary to import coolies from India, for Burman labour cannot be relied upon in sufficient quantities to run a large pulp-mill.

Carts are procurable in small numbers only, so that here again importation will be necessary. It is not generally possible to hire elephants, and if it were contemplated to use them for dragging purposes they would have to be purchased.

(11) *Firewood.*

Firewood cannot be obtained easily, for though large quantities are forthcoming from the forests, the difficulty in exploiting it would be considerable. Were it to be floated down the streams, it would probably interfere either with the floating of the teak or with the bamboos, while carting would be too expensive. Coal will, therefore, be necessary, and its price would be but little higher than in Rangoon, especially were the site of the factory to be fixed not far up the river from Rangoon and at a place in direct connection with that port.

(12) *Chemicals.*

No lime is available in the vicinity of the Okkan Reserve, so that it will have to be procured from Rangoon, where the price is 5 annas per cubic foot. Excellent lime is procurable in large quantities from Moulmein. All other necessary chemicals will have to be imported to Rangoon by sea, and taken up the Rangoon river to the factory.

(13) *Miscellaneous facts.*

The proposed site for a mill at Okkan is surrounded on every side by open country, generally under rice cultivation. It is a fairly

healthy locality throughout the year and is well suited to Europeans. It has the advantage of being on a good floating stream and also on the railway, some 50 miles from Rangoon. It is possible that, were a mill to be erected on a large scale, a better site would be further down the river, a few miles above Insein and near Rangoon, but such a point can only be settled by the firm or company intending to start the business.

BURMA BAMBOO AREA NO. III. (*See portion marked C on map.*)

Pyinmana Division.

(1) *Name and Situation.*

The area from which bamboos can be extracted from the Pyinmana Division is a block of forests at the foot of, and on the eastern slopes of the Pegu Yomas, commencing some 10 to 15 miles east of the Rangoon-Mandalay Railway. The forests are of two types, the northern portion being in the dry zone and consisting of a poor quality Cutch forest, the central and southern portions being in the wet zone, and containing teak, pyinkado, and bamboos. It is with the latter type of forest that we are concerned. For the purpose of working out the timber from this area, it has been divided into nine blocks, of which four are drained by the Ngalaik and five by the Yonbin, both of these rivers finding their way into the Sittang, to the east and south-east of the town of Pyinmana.

(2) *Description of the forest.*

(*1*) *The Ngalaik drainage.*—The following blocks make up the catchment area of the Ngalaik :—

(*i*) The Taungyé Reserve is the most northern block, and is drained by a tributary of the Ngalaik, which bears the same name as that of the Reserve. The river in its upper reaches is a poor floating stream, so that the upper portions of the forest are excluded from this scheme, though bamboos cover nearly the whole area.

(*ii*) The Ngalaik Reserve lies inside the Taungnyé, with its north-west limits covering the crest of the Yomas, in which locality bamboos occur, but would be difficult to exploit.

(*iii*) The Kaing Reserve is a small area of forest, to the south-east of the Ngalaik Reserve and is drained by the Ngalaik itself.

(*iv*) The Pozaungdaung Reserve lies close to the Railway on hilly ground, but not on the main ridge of the Yomas; it is well stocked with bamboos, of which a certain number are extracted annually from its eastern edge by small contractors. The tributary of the Ngalaik, known as the Chaungmagyé, drains this area.

(2) *The Yonbin drainage.*

(*v*) The Yanaungmyin Reserve is a comparatively small area lying on undulating ground on the outside edge of the Yoma blocks, and is drained by a small river called the Thebyu, a tributary of the Yonbin.

(*vi*) The Plawé Reserve is the most northern block drained by the Yonbin. It lies up against the main ridge of the Yomas, consequently it is difficult to extract bamboos from its upper reaches. It is drained by the Palwé Chaung, a tributary of the Yonbin, and a good floating stream.

(*vii*) The Yonbin Reserve in the west lies on the main ridge of the Yomas, and is drained by the Chaungmangyi tributary, also a good floating stream.

(*viii*) The Mynbyin Reserve lies to the south of the Yonbin forests, and is tapped by the Yonbin Chaung, a good floating stream.

(*ix*) The last reserve is the Yeni, which contains fine pyinkado forests. It has been decided to omit this area from the scheme as the river by which it is drained is a poor floating stream.

(3) *Area.*

In calculating the area of forests of the various reserves over which bamboos occur, those lying along the main ridge of the Yomas have been excluded, as the difficulty in exploiting the bamboos from that locality would probably render the cost excessive.

Besides the above localities, certain of the areas contain a type of forest known as " Indaing " in which bamboos are non-existent, while others are covered with bamboos unsuitable for pulping. To arrive at the areas, over which *Bambusa polymorpha* (Kyathaung) and *Cephalostachyum pergracile* (Tinwa) occur, Mr. Leete, the Divisional Forest Officer, was consulted and also his Assistants, many of whom have many years' experience of these forests.

In this way the following figures have been arrived at :—

Name of Reserve.	Actual area of Reserved Forests, in acres.	Area covered by exploitable Kyathaung and Tinwa bamboos, in acres.
(*i*) Toungnyé Reserve	69,546	34,773
(*ii*) Ngalaik ,, ...	80,013	60,009
(*iii*) Kaing ,, ...	13,341	10,005
(*iv*) Pozaungdaung ,, . . .	51,557	12,889
(*v*) Yanaungmyin ,, ...	13,078	6,539
(*vi*) Palwe ,, ...	89,222	44,611
(*vii*) Yonbin ,, ...	78,034	39,017
(*viii*) Mynbyin ,, ...	127,059	63,529
	521,850	271,372 acres or 424 sq. miles

(4) *Species of bamboos and mode of growth.*

The species of bamboos which predominate in these forests are *Bambusa polymorpha* (Kyathaung) and *Cephalostachyum pergracile* (Tinwa). Other species occur such as *Oxytenanthera albociliata* (Wanwé), *Dendrocalamus strictus* (Myin) on the drier ridges, and others, but only Kyathaung and Tinwa are taken into consideration for the purposes of this scheme.

The *Bambusa polymorpha* (Kyathaung) and *Cephalostachyum pergracile* (Tinwa) grow to a large size in these forests, especially the former. In order to ascertain the girth, length and weight of culms of these

species (see Appendix II), 200 Kyathaung and the same number of Tinwa were cut and measured. The former gave average measurements of 10·1″ mid-girth and 49 feet in length, the thin tops being cut off. In the same way 200 Tinwa were cut, giving an average mid-girth of 6·3″ and a length of 38 feet. The weight of these bamboos green and of the dry internodes is dealt with under the heading (6) Outturn.

(5) *Factory site.*

The obvious site for a factory is somewhere on the Sittang river, but no suitable place exists over its course through the Pyinmana Division as the Railway runs at some distance from the river. It will, therefore, be necessary to fix a site lower down in the Toungoo Division, and the place suggested by Sindall in his report on the possibility of pulp manufacture in Burma (1906) is at the village of Kywebwé, which lies on Railway some 18 miles below Toungoo (see map). On visiting this place it was found that the river was two miles distant from Kywebwé and that it would be better to place the mill at Myozo, on the Sittang, which here runs between high banks (see map). A road, which was at the time of inspection in very bad order, joined the river with the rail. To exploit bamboos from the Pyinmana forests would necessitate floating an average distance of 40 miles down the Ngalaik and its tributaries and 120 miles from the junction of the Ngalaik and Sittang to the mill at Myozo.

All chemicals, except possibly lime, would either have to be railed up from Rangoon, a distance of 186 miles, or brought up the Sittang in boats, as the river is sufficiently deep to allow boats of 25 tons burden to ply up to Myozo.

(6) *Outturn.*

A certain number of bamboos are exploited annually from the Pyinmana forests by purchasers and right-holders; in 1909-10 the number taken out by the former was 72,700 and by the latter the number is estimated at 300,000. Compared with many other divisions in Burma this is a very small number.

The possible outturn of Kyathaung and Tinwa bamboos is based on the enumerations made in the Pyinmana and Toungoo Divisions and on weighings taken of a large number of cut stems. It has been thought advisable to take the average of the countings in both Divisions, as the

forests in both localities are very similar, being situated on the eastern slopes of the Pegu Yomas.

From Appendix II it will be seen that the average yield of dry internodes of both Kyathaung and Tinwa is 39,047 lbs. or 17·6 tons per acre. The area of forests covered by these bamboos is 271,372 acres, giving a gross yield of 9,596,262,284 lbs. or 4,775,147 tons of dry internodes. Estimating that the forests can be cut over once in five years, the possible sustained yield of dry internodes works out at 955,029 tons per annum.

(7) *Lines of export.*

The bamboos will have to be dragged from two to three miles to the nearest floating stream, and thence floated down the Ngalaik and Yonbin Chaungs to the Sittang river. Floating is only possible in the rains, and even then only in times of flood. This would seem to rule out these forests as a suitable locality whence the raw material could be exploited ; on the other hand, very large quantities of teak are floated down annually by these streams, and there appears to be no reason why bamboos should not also be extracted in the same way. Mr. Leete, the Divisional Forest Officer, expressed it as his opinion that the work could be carried out without difficulty. On the Sittang floating is possible throughout the year.

The only forest in which it is possible to exploit bamboos by carts is the Yanaungmyin Reserve, and this could only be done in the open season.

The various distances over which it will be necessary to float bamboos the forest to the Sittang are as follows, the distance from the junction of the Sittang and Ngalaik to the mill being 120 miles :—

(*i*) The Taungnyé Reserve, from 20 to 40 miles.
(*ii*) The Ngalaik Reserve, from 45 to 60 miles.
(*iii*) The Kaing Reserve, from 30 to 40 miles.
(*iv*) The Pozaungdaung Reserve, from 20 to 40 miles.
(*v*) The Yanaungmyin Reserve, 20 miles.
(*vi*) The Palwé Reserve, from 35 to 60 miles.
(*vii*) The Yonbin Reserve, from 25 to 50 miles.
(*viii*) The Minbyin Reserve, from 29 to 50 miles.

At present the rafting work on the Ngalaik and Yonbin is done by local men, two men bringing down a raft of 150 Kyathaung, or of 200

Tinwa. On reaching the Sittang the rafts are enlarged and contain 1,000 stems or over.

(8) *Cost of cutting and extraction.*

The price of bamboos in Pyinmana is Rs. 5 to Rs. 6 per 100 for Kyathaung in the rains and Rs. 8 per 100 in the open season. Tinwa are generally sold at a little over half that rate.

The cost of cutting and dragging to the river, an average distance of 1½ miles, comes to Re. 1-8 per 100 for Kyathaung. The cost of floating, from the centre of the forest to the Sittang, costs Rs. 3-8 and the cost of floating in large rafts to the mill at Myozo is estimated to cost Rs. 2-8. The total cost of landing Kyathaung at the mill, therefore, works out to Rs. 7-8 per 100. Tinwa being much smaller and more easy to handle, the total cost is put at Rs. 6 per 100.

(9) *Cost of landing dry internodes per ton at the mill.*

From Appendix II, it will be seen that a Kyathaung bamboo yields 25·6 lbs. and a Tinwa yields 12·05 lbs. of dry internodes. Therefore, it takes 87 Kyathaung and 186 Tinwa to make up a ton of dry internodes. The cost of exploiting 100 Kyathaung to the mill costs Rs. 7-8 and of 100 Tinwa Rs. 6, so that the cost of landing one ton of dry internodes of Kyathaung at the mill works out to Rs. 6-8-5 and of Tinwa to Rs. 11-2-6.

(10) *Labour.*

The general opinion of the local officers is that sufficient labour will be forthcoming in the rains to exploit one and a half million bamboos and that petty contractors will be found to do the work. If more labour is necessary it will have to be imported. The price of labour is 8 annas per man, but in the harvest season it is generally higher. Burman carpenters and masons are procurable at Re. 1 per day, while Chinese carpenters can earn as much as Rs. 2 per day.

(11) *Chemicals.*

The cost of lime is 8 annas per 100 lbs. in Pyinmana. It is procured from a village called Chaungza, in the Paunglaung Range, about 6 miles east of the railway. The lime-stone is obtained from surface workings,

20 to 25 kilns being worked by the local population. The strata are said to be fairly extensive, and the lime is of excellent quality, though the former statement requires verification.

(12) *Fuel.*

As the proposed factory site is in the Toungoo Division. the question of the supply of fuel must be considered for that locality. It is plentiful and can be brought down by boat to the mill door at a cost of Rs. 8 to Rs. 10 per ton.

(13) *Miscellaneous.*

The Pyinmana forests contain large quantities of pyinkado, a timber that does not float, and it has been suggested that, if this were sold, the bamboos required to float it out might afterwards be used as raw material for the manufacture of paper-pulp. The mill site suggested at Myozo lies in the wet zone but is, generally speaking, not unhealthy, and is a quiet and suitable place for Europeans to live in, provided proper accommodation is available. The Pyinmana forests are not healthy in the rains, especially during November, though the large firms working out the timber in these forests employ European supervision throughout the wet season.

BURMA BAMBOO AREA NO. IV. (*See portion marked* ***D*** *on map*).

Toungoo Division.

(1) *Name and Situation.*

(*i*) *Areas to the west of the Sittang river.*

The main ridge of the Pegu Yomas runs parallel to the Sittang and the railway at a distance of 50 miles. Between the hills and the river occur 14 Forest Reserves, the main block lying up against the hill range, while outlying blocks occur nearer, though never touching the Sittang river. The whole of these forests are drained by feeders of the Sittang, of

which the Kabaung and the Swa are the most important for floating purposes (see map). Of the 14 reserves, only four are suitable for the extraction of bamboos, namely, the Bondaung and Kabaung in the south drained by the Kabaung tributary and the East Swa and Saing Yané Reserves drained by the Swa. The other reserves are either too distant or are drained by rivers in which floating is difficult.

(ii) *Areas to the east of the Sittang river.*

To the east of the main stream are found four reserves of small size; moreover, there are extensive areas of unclassed forest containing many bamboos. The most important tributary on this side of the river is the Thaukyegat, which joins the Sittang near Toungoo. This river drains extensive Unreserved Forests. To the north of this river, there are six small tributaries in the Toungoo Division, all of which pass through Unreserved Forests containing bamboos.

(2) *Description of the forests.*

The four blocks to the west of the river, with which this scheme deals, are situated on hilly ground, rising in places to over 1,000 feet. The northern portion of the Bondoung Reserve is drained by the Kabaung, while the southern portion is drained by a small tributary down which it would be difficult to float bamboos and so it has been excluded from the bamboo-yielding area.

The Kabaung reserve, which lies to the west of the above reserve, is drained down the centre by the river of the same name. It is not possible to extract bamboos from the whole reserve, as the Kabaung is a rocky stream above its junction with the Kyetsha Chaung.

Both blocks contain dry to moist deciduous teak, pyinkado and bamboo forest, the chief species of bamboo being *Bambusa polymorpha* (Kyathaung), while *Cephalostachyum pergracile* (Tinwa) also occurs in fair quantities, but is still immature having flowered in recent years. The type of forest in the two northern blocks, on the Swa River, resembles that in the Kabaung Reserve, but is somewhat drier, the East Swa Reserve being drained by the main stream and its tributary the Lonyan Chaung, while the Saing Yané Reserve is drained by a tributary known as the Saing Chaung, which in its upper reaches is not a good floating stream.

To the east of the Sittang, the Thaukyegat Chaung is the most important tributary and drains extensive areas of Unreserved Forests, containing much pyinkado and bamboos, as also in places "Indaing" (*Dipterocarpus tuberculatus*) in which the bamboo is scarce or entirely absent. To the north of this river occur smaller forests from which a certain number of bamboos could also be exploited.

(3) *Area.*

The reserved forests of this Division are very extensive and contain masses of bamboos. As was mentioned before, many of these forests are remote from good floating streams or floating is not practicable along some of the larger rivers, such as the Pyu and Kun, owing to the presence of rocky gorges where they enter the plains. For this reason, the areas from which bamboos can be exploited are relatively small as compared with the total areas under forest.

The forests from which bamboos can be extracted are as follows :—

Name of Reserve.		Actual area of Reserved Forests, in acres.	Forests from which bamboos can be exploited, in acres.
Kabaung drainage	Bondaung Reserve . .	23,757	10,330
	Kabaung Reserve . .	188,934	17,240
	Unreserved Forest . .	Not known.	10,000
Swa drainage	East Swa Reserve . .	13,555	....
	Lower Saing Yané Reserve	70,176	15,000
Thaukyegat drainage.	Unreserved Forest, east of the Sittang.	Not known but very large.	10,000
Drainage of six small feeders of the Sittang.	Unreserved Forest on east bank of the Sittang and north of Toungoo.	Ditto .	12,000
		..	74,570

Both Mr. Rorie, the Divisional Forest Officer, and the writer of this report consider the estimate of 74,570 acres to be a low one, and well on the safe side.

(4) *Species of bamboos and mode of growth.*

By far the most abundant species of bamboo found in the Toungoo forests is *Bambusa polymorpha* (Kyathaung). It grows here to a large size, averaging 49 feet long when cut off at 2″ girth at the thin end and with a mid-girth of 10·1″. *Cephalostachyum pergracile* (Tinwa) comes next in importance after Kyathaung. This species flowered about 1905, the old clumps after producing seed died down and at present the ground is covered with seedlings which in a few years will produce large quantities of bamboos.

Bambusa Tulda (Thaikwa) and *Dendrocalamus strictus* (Myinwa) occur locally in fair quantities but are not nearly so abundant as the first two species mentioned.

(5) *Factory site.*

The factory site is the same as that proposed for the Pyinmana scheme, namely Myozo, some 18 miles down the Sittang from Toungoo. (See map.)

(6) *Outturn.*

The number of bamboos exploited in 1909-10 from the Reserved and Unreserved Forests of the Toungoo Division was as follows :—

From Unreserved Forests.

Range.	Locality.	Number.	Rate.	Amount.
			Rs. a. p. per 100	*Rs. a. p.*
Pyunchaung . .	Unreserved . . .	200,200	0 5 0	625 10 0
Pyu . . .	Ditto . . .	258,700	0 5 0	808 7 0
Yedashé . . .	Ditto . . .	11,200	0 5 0	35 0 0
Thagaya . .	Ditto . . .	16,800	0 5 0	52 8 0
Gwethé . . .	Ditto . . .	149,500	0 5 0	467 3 0
Kabaung . .	Ditto . . .	192,700	0 5 0	602 3 0
	Total Unreserved Forests .	829,100		2,590 15 0

From Reserved Forests.

Range.	Locality.	Number.	Rate.	Amount.
			Rs. a. p. per 100	*Rs. a. p.*
Pyunchaung . .	Chaungmaugé Reserve .	300	0 5 0	0 15 0
,, . .	Mezindein Reserve .	12,000	0 5 0	37 8 0
Pyu . . .	Kauguthuri Fuel Reserve.	1,000	0 5 0	3 2 0
,, . . .	Myayabin Reserve .	2,100	0 5 0	6 9 0
Thagaya . .	Myohlabes ,, . .	20,900	0 5 0	65 5 0
,, . . .	E. Swa ,, .	38,000	0 5 0	118 12 0
,, . . .	Saing ,, .	8,400	0 5 0	26 4 0
Yedashé . . .	Lonyan ,, .	1,500	0 5 0	4 11 0
,, . . .	W. Swa ,, .	12,700	0 5 0	39 11 0
Gwethé . . .	Gwethé ,, .	5,600	0 5 0	17 8 0
,, . . .	Kanin ,, .	3,100	0 5 0	9 11 0
Kabaung. . .	Kabaung ,, .	47,200	0 8 0	236 0 0
	Total Reserved Forest	152,800	..	566 0 0
	GRAND TOTAL .	981,900	..	3,156 15 0

The possible outturn of Kyathaung and Tinwa bamboos is based on the enumerations made in the Pyinmana and Toungoo Divisions, the latter countings having been made by Mr. Rorie, the Divisional Forest Officer. The calculations of the weight of the green bamboos and dry internodes is based on weighments made of 200 average Kyathaung and 200 Tinwa bamboos, cut in the forests in which the enumeration plots were taken. From Appendix II it will be seen that the average yield of dry internodes of both Kyathaung and Tinwa is 39,047 lbs. or 17·6 tons per acre. The area of the forest, from which it is possible to exploit these bamboos, is 74,370 acres, giving a gross yield of 2,903,925,390 lbs. or

1,309,212 tons of dry internodes. Estimating that the forests can be cut over once in five years, the possible sustained yield of dry internodes works out at 261,842 tons per annum.

(7) *Lines of export.*

The bamboos will have to be dragged a maximum distance of two miles to the rivers after being cut, and floated down to the Sittang and again some 20 miles down that river to Myozo, the proposed factory site. The chief floating streams are as follows :—

(*i*) The Kabaung, a large stream down which bamboos can be floated up to the end of February. This river taps the Bondaung and Kabaung Reserves. Above the point where its tributary the Kyetsha Chaung comes into the main stream, the bed is rocky, so that the area above this point has been excluded from this scheme. To overcome this difficulty of floating in streams with rocky beds, Mr. Walker, Burma Forest Officer, has suggested cutting up the bamboos into sections, each section to contain at least 2 internodes, so that an air-tight chamber occurs in each piece and then to float them down separately. This has never been done but would seem to be a by-no-means impossible way of getting over the difficulty.

(*ii*) The Swa river, which taps the East Swa Reserve, enters the Sittang some 40 miles above the proposed mill site at Myozo. Its tributary the Saing Chaung, which is also a large stream, taps the Saing Yané Reserve. It is a good floating stream down which bamboos can be brought from the village of Lonyanbauk up to the end of February.

(*iii*) The Thaukyegat is a large perennial stream on the east bank of the Sittang, and joins that river just below Toungoo. It possesses the great advantage in that bamboos can be floated down its channel throughout the year.

(*iv*) Bamboos can also be obtained by floating them down the other small streams which occur on the east bank of the Sittang, to the north of Toungoo.

(*v*) Small quantities of a few hundred tons can also be extracted by carts from the hill forests directly west of Myozo, the lead by road being not more than seven miles.

(8) *Cost of cutting and extraction.*

The present price of Kyathaung in Toungoo is Rs. 6 per 100 and Rs. 6 to Rs. 7 per 100 for Tinwa.

The cost of cutting and dragging Kyathaung to the floating streams is put at Re. 1-8 per 100; the cost of floating to the Sittang, from the centre of the Kabaung or East Swa Reserves, is estimated to cost Rs. 3-8 per 100; and the cost of preparing large rafts and floating them down the Sittang, an average distance of 30 miles, is put at Re. 1-8, giving a total of Rs. 6-8 per 100 landed at the mill. Tinwa, being smaller and easier to handle, can be brought out for Rs. 5 per 100.

(9) *Cost of landing dry internodes per ton at the mill.*

From Appendix II it will be seen that a Kyathaung bamboo yields 25·6 lbs. and a Tinwa yields 12·05 lbs. of dry internodes. Therefore it takes 87 Kyathaung and 186 Tinwa to make up a ton of dry internodes. The cost of exploiting 100 Kyathaung to the mill costs Rs. 6-8 and 100 Tinwa Rs. 5, so that the cost of one ton dry Kyathaung internodes at the mill works out to Rs. 5-10-6 and of Tinwa to Rs. 9-4-9.

(10) *Labour.*

Mr. Rorie, the Divisional Forest Officer, Toungoo, anticipates difficulty in procuring an adequate supply of labour, and it is fairly certain that it will be necessary to import coolies from outside the district. In order to indicate the wages now being paid at Myozo, the proposed mill site, it may be stated that a cooly earns Rs. 13 to Rs. 15 per month working at the Myozo Saw-mill, and that the Engineer-in-charge is paid Rs. 110 per mensem.

(11) *Chemicals.*

The cost of lime at Toungoo is 8 annas per 100 lbs. and this must be either procured from the Pyinmana Division (see page 58) or from Rangoon or Moulmein. It is just possible that the other necessary chemicals could be run up the Sittang in boats, but on this point it is difficult to make any statement with certainty. Otherwise they would have to be railed up from Rangoon to Kywebwé and carted two miles to Myozo.

(12) *Fuel.*

Fuel is plentiful in this Division, and a certain amount could always be procured from the many saw-mills along the Sittang. It can also be obtained by floating it down the river from the Unreserved Forests. It would probably cost from Rs. 8 to Rs. 10 per ton landed at the mill.

(13) *Miscellaneous.*

The remarks made on page 59 regarding the possibility of floating out bamboos in conjunction with pyinkado apply with equal force to this Division. The great advantage of utilizing these forests for the supply of raw materials lies in the fact that floating can be carried out throughout the year down the Thankyegat Chaung.

Myozo is a healthy place, though the forests during November and December are by no means healthy. The most difficult point to be settled is the labour question, about which it is difficult to obtain reliable information.

Burma Area No. V.

Arakan Division.

(1) *Name and Situation.*

The conditions which indicate the feasibility of extracting bamboo for paper-pulp in other districts of Burma, which have been described above, differ *in toto* in Arakan. The species of bamboo is different to that found in Burma proper, while the local conditions are peculiar to Arakan, and will therefore require to be described in detail.

The forests from which bamboos can be extracted cover the various catchment areas, the drainage of which finds an outlet at or near the seaport of Akyab (see map). This part of the district lies north and northeast of Akyab and is drained by three large rivers, namely the Mayu to the west, the Kaladan in the centre and the Lemru to the east. The Arakan coast-line here runs more or less north-west and south-east, while the three above-mentioned rivers run from north to south converging on Akyab, and are separated by parallel lines of hills rising to about

300 feet. Owing to the existence of a waterfall on the Seik Chaung, a tributary of the Mayu, which occurs about 60 miles from the sea and which it is thought, might possibly be utilized to generate power for a mill, this scheme has been divided into two parts. The first dealing with the forests lying above this waterfall, the raw produce from which could be worked out to a mill just below the falls, and the other dealing with the forests on each side of the Kaladan and Lemru, the bamboos from which could be exploited to Akyab.

A.—Forests of the Seik catchment area.

(*See small portion marked E on map.*)

(2) *Description of the forests.*

The catchment area, in which these forests occur, is, generally speaking, narrow and long, the main stream having few feeders of importance throughout the area, except one on the east bank, called the Rhee Chaung, which is nearly as large as the main stream and joins it just above the waterfall. The forests were originally of an evergreen type but this class of forest has gradually disappeared and is now found only along the banks of the rivers and on the steeper slopes. The rest of the area is now covered with a dense crop of bamboos, known locally by the name of Kayin (*Melocanna bambusoides*), in which practically not a single tree is to be seen. This peculiar type of bamboo growth has been brought into existence by a method of shifting cultivation known as "Taungya." It is carried out by the hillmen and consists in cutting down the original forests, burning the timber and brushwood when dry and sowing rice and cotton seed in the ashes; they then desert the place, after reaping the crop, and go on to another area. As this system of cultivation has been going on for many generations, the original forests have practically disappeared, leaving these hill tracts covered with masses of bamboos of varying ages.

Each household cuts about three acres a year, and now that the people have cleared out the virgin forests, they go back every six or seven years to their original area and instead of cutting and burning tree growth, which has, as a matter of course, disappeared, they clear out the six to seven-year old bamboos, and burn them in order to obtain the ash in which to sow the seed.

(3) *The area of forests covered by bamboos.*

The areas dealt with are not organised; in other words, no Working-Plans have been prepared, so that the exact size of the catchment area of this river is not known. From the available maps it would appear to be about 150 square miles, of which 90 square miles may be taken into account, from which it is possible to exploit bamboos, namely, one mile on each side of the river, from a point above the waterfall and similarly one mile up each side of its tributary, the Rhee Chaung. This figure has been arrived at after inspecting the greater portion of the whole area.

(4) *Species of bamboo and mode of growth.*

The species found in these forests is *Melocanna bambusoides*, with a comparatively small thin-walled stem, which does not grow in clumps, like most other bamboos, but sends out shoots from a ramification of rhizomes in the same way as suckers are put out by tree roots. The result of this mode of growth is that the ground is covered with stems standing at more or less equal distances, one from another, and not in clumps, as is generally the case with such species as *Cephalostachyum pergracile* or *Bambusa polymorpha*. A number of stems were measured on a recently cut "taungya" area, which was covered with seven-year-old growth, and were found to average 20·1* feet in length and 3·0″ mid-girth. Another lot numbering 10,575 was cut by Mr. Walker, Divisional Forest Officer, Arakan, and gave an average of 22 feet in length and 3·8″ mid-girth (see Appendix III).

As has been mentioned above, the bamboo forests contain blanks under cultivation, and elsewhere growth of one, two, three, and up to seven-year-old bamboos, each age-class being separate. The one-year-old growth is about 12 feet high, the second about 15 feet, until at seven years of age it is from 30 to 35 feet high.

(5) *Possible factory site.*

The reason for dividing this scheme into two parts is that there occurs a fine waterfall on the Seik Chaung, above the village of Ponnyaleik, the fall being some 60 miles up the river from Akyab, while the other two catchment areas in this part of the country drain down direct to that town and could therefore not be conveniently worked out to a mill

*Note.—The thin end having been cut off before the culms were measured.

situated just below the falls. In the event of the falls being utilized for the purpose of working a pulp-mill, the site could be chosen below the falls and the area above utilized for the extraction of the bamboos.

The falls are situated on the Seik Chaung, shown on the map south of the smaller portion marked E, and just outside the bamboo area. The Seik Chaung is a large tributary of the Mayu river, and at the place, where they meet, the river is about 200 yards broad. The falls themselves consist of three steps, the upper one having a drop of 16 feet and separated from the second by a sloping ledge 300 yards long, falling some 14 feet over its length. The middle falls are 30 feet high and are divided from the third or lower fall by a stream 100 yards in length, which drops 20 feet, the lower cascade being about 10 feet in height. The total fall of the river over a distance of 400 yards, is therefore about 90 feet.

The cause of these falls is due to a peculiar formation of rock running at right angles across the river like a wall, a feature which is especially marked on the upper falls, so that there would be little difficulty in training the stream in order to concentrate the flow of water into one channel. On either side of the falls, the banks of the stream are precipitous, especially on the west side; on the east bank, there occurs a ledge or spur along which the water could be taken, were the stream to be tapped at the upper falls. This ledge runs down the east bank for about half a mile and emerges on to a fairly level stretch of open ground, on which a mill could be erected.

During the monsoon months a great volume of water passes over these falls but diminishes as the dry season advances. At the time when these falls were inspected, at the beginning of February, the stream flowing over the central falls was about 40 feet broad with a very fair volume of water coming over. In the event of these falls being taken into consideration as a possible power station for a pulp-mill, it would be necessary for the interested parties to send an engineer to inspect them during April, so as to ascertain the power available during the dry months.

The proposed site below the falls has also the great advantage that large lighters and small steamers can come up to this point throughout the year at high tide, and thus connect up the place directly with the seaport of Akyab.

Lastly, fresh water is obtainable at this place in large quantities which is a distinct advantage, especially in a locality where most of the streams are tidal for long distances up from the sea.

(6) *Outturn.*

A sample plot was taken by Mr. Walker, Divisional Forest Officer, Arakan, in which he clear cut exactly one acre of bamboo growth, and counted and weighed all the stems. The results of this operation are given in Appendix III. As the nodes in this species of bamboo are very small, they have not been taken into account as both internode and node can be pulped together. The yield, per acre, of dry stems is 16,576 lbs, the area from which bamboos can be extracted is estimated to be 57,600 acres, so that the gross yield works out to 426,240 tons. Working on a seven-year-rotation we get an annual sustained yield of 60,891* tons.

Though the quantity of bamboos stated above could be exploited annually, at present the whole of the bamboo forests are worked over by the Taungya cutters who monopolise the whole areas, so that, unless these cutters were largely restricted or entirely turned out, there would be no place for a mill. The Taungya cultivators leave a surplus which would be available for the mill but it would not in any way be sufficient to keep it running throughout the year. It would, therefore, be imperative for the interested parties to approach the Burma Government before prosecuting further enquiries in this locality.

A possible solution to the difficulty would be to employ the Quamis who cultivate this area, in cutting and extracting the bamboos, though it would have to be borne in mind that they are a hill tribe knowing little about contract obligations and therefore could not be relied upon, until they had been taught to work more methodically than at present.

(7) *Lines of export.*

The Seik Chaung, down which the bamboos can be floated to the falls, is 50 yards wide, 30 miles above the proposed mill site, increasing to 200 yards at the falls. Over the upper 25 miles of its course it is a deep channel flowing slowly between steep banks, covered with dense evergreen forest. These forests are, however, only a fringe along its banks, while the hills above are covered from end to end by a dense pure crop of bamboos.

*Note.—This is thought to be an extremely conservative figure.

The last five miles to the falls are a series of cataracts divided by deep holes, the bad portions of the channel being more or less divided into three sections. At present, bamboos are floated down the entire length of the river, being dragged over the rocky portions, while, at the main falls, they are thrown down and collected into large rafts in the deep pools at the foot of the falls. Without doubt, the stretches, over which floating is at present difficult, could be greatly improved by clearing the main channel of boulders and rocks, and this at no great expense. The stream in February was found to be broad and the amount of water was quite sufficient for rafting purposes. Probably for two months of the hot weather, dragging would be necessary over short lengths of difficult channel within five miles of the main falls.

The stream below the falls is deep and broad so that a pulp-mill, situated on the east bank of the river, would be in direct communication by water with Akyab, a port that large steamers can enter throughout the year.

(8) *Cost of cutting and extraction.*

The Seik Chaung, above the falls, has a long narrow catchment area, so that, the distance, over which the bamboos will have to be dragged to the stream, will not exceed one mile. On the other hand, with the exception of the Rhee tributary, there are few by-streams down which floating is possible. The present cost of extracting bamboos to the falls is Re. 1 per 100; were work to be carried out on a large scale, under proper supervision, the cost could no doubt be reduced. The price of bamboos in Akyab is at present Rs. 2 per 100.

(9) *Cost of landing dry stems per ton at the factory site.*

The weight of 10,575 dry stems is 16,576 lbs. so that 100 stems weigh 155 lbs. The weight of the nodes, as before stated, need not in this case be taken into consideration. It therefore requires 1,452 bamboos to make one ton. The cost of landing 100 bamboos at the falls is Re. 1, so that the cost of one ton of bamboos at the proposed factory site, *i.e.*, just below the falls, comes to Rs. 14-8-1.

(10) *Labour.*

It is probable that, if Government decides to stop Taungya cutting in any given area, it will insist on a serious attempt being made to employ

the local cutters in felling and extracting the bamboos. In any case Chittagong coolies, who come over in great numbers during the harvest season, would be available. A labourer can earn 8 annas a day and during the rice harvest probably double that amount.

(11) *Firewood.*

Were the falls utilized for working a power station, a considerable reduction could be made in the amount of fuel required.

(12) *Chemicals.*

Good lime is available from Ramree Island, close to Kyaukpyu, a fair quantity of which is annually imported to Akyab, where it fetches Rs. 65 per 100 maunds (80 lbs. per maund). It is probably possible to obtain coral outside Akyab harbour, but this point requires verification. All other chemicals necessary will have to be imported by sea to Akyab port.

(13) *Miscellaneous.*

The whole scheme is based on the assumption that Taungya cutting will be restricted or stopped, otherwise all hope of success must fall to the ground. The area and local conditions appear to be admirably suited for the purpose of the pulp-mill, as dense forests of bamboos occur in this catchment area, the river is well suited to floating, especially if the channel just above the falls is improved, big boats can come right up to the proposed mill site from Akyab, the cost of extraction is not prohibitive, while the waterfall may quite possibly be found suitable for working a mill.

B.—Forests of the Kaladan and Lemru catchment areas.

(*See large portion marked E on map.*)

(1) *Description of the forests.*

The Kaladan and Lemru are two large streams, having their sources far up in the Arakan Hill Tracts, flowing southwards between parallel ranges of hills and both finding an outlet at the sea-port of Akyab. The

Kaladan is the larger of the two streams, with several large tributaries, the most important of which are the Yo and Pi Chaungs on its west bank, and the Mi Chaung on its east bank. It is navigable for large launches up to Paletwa, some 100 miles from its mouth.

The Lemru lies to the east of the Kaladan and is navigable up to a point about 60 miles from the sea. It has many large tributaries, the most important of which are Tagwé, Wat and Than Chaungs on its east bank and the Ru Chaung on the west bank. Both the Kaladan and Lemru pass through bamboo forest in the upper half of their courses, while their tributaries tap extensive bamboo areas in the by-valleys. The type of forest in these localities is the same as that described in Part A being, generally speaking, covered with bamboos resulting from "Taungya" cutting.

(2) *Area of forest covered with bamboos.*

The area of Protected Forest north of Akyab, as given in the Administration Reports, is 8,050 square miles. It is not possible to state, with accuracy, what portion of this is covered by bamboo growth, but from the general aspect of the country it is put at 3,000 square miles, which is probably a low estimate.

(3) *Species of bamboo and mode of growth.*

The species of bamboo, its mode of growth, and the system under which the forests are worked by Taungya cutters, are the same as described in Part A.

(4) *Possible factory site.*

In this case the proposed site is at Akyab, for the reason that both rivers find an outlet at this port, and that the bamboos from both areas can be brought down to this place without difficulty. The chief difficulty, which presents itself here, is the supply of fresh water, as the only source available is a tank which supplies the town. At present the quantity available is hardly sufficient for domestic purposes, and a scheme has been started to increase the supply, so that there will be about one million gallons in excess of what is necessary for the town of Akyab. This amount would not be sufficient for a pulp-mill, so that further storage tanks would have to be prepared. Otherwise Akyab presents many advantages, being a good port and geographically well situated.

(5) *Outturn.*

It is not possible to give any figures of outturn for these localities. The conditions described in Part A of this scheme apply to these forests, namely, that the bamboo growth is cut over by Taungya cutters every 6th or 7th year, and that the bamboo forests are monopolized by them for this purpose. On the other hand, as the area of forest is in this case very large, the surplus supply of bamboos, over and above that utilized by Taungya cutters, is considerable. As an instance in proof of the above statement, it may be pointed out that the amount taken out in 1908-09 to meet the local demand amounted to 779,900 stems from the Kaladan and 1,050,300 from the Lemru catchment areas.

To obtain a large supply of bamboos, it would be necessary to go far up into the hills, as the local supply, which is obtained from the balance left over by the Taungya cutters, comes from areas relatively close to Akyab.

Owing to want of time, it was only found possible to carefully inspect the Seik catchment area, so that in the event of any persons wishing to go further into the matter, a more detailed enquiry into the Kaladan and Lemru catchment areas would be necessary.

As stated above, it is not possible to give definite figures of outturn, as it is not known what amount will be available after the "Taungyas" have been cut each year and the local demands have been satisfied. It must, however, be considerable, and it is thought that a sufficient quantity will be available to run a large pulp-mill. Were the "Taungya" cuttings restricted or stopped, the supply would be enormous.

(6) *Lines of export.*

Floating is feasible throughout the year, even in the upper reaches of the Kaladan, the Lemru and their tributaries ; in this connection no difficulties are anticipated.

(7) *Cost of cutting and extraction.*

The price of bamboos at Akyab is from Re. 1-12 to Rs. 2 pe 100. This includes cost of extraction, floating, profit to the contractor and 5 annas for royalty. Were bamboos to be exploited on a large scale, they could be landed at Akyab at Re. 1-8 per 100.

(8) *Cost of landing dry internodes per ton at the mill.*

From weighments of ten-year-old dry bamboos taken by Mr. Walker (see Appendix III) a dry bamboo was found to weigh 1·55 lbs., so that it requires 1,452 bamboos to make a ton. The price is Re. 1-8 per 100 at Akyab, so that the cost of one ton of raw material comes to Rs. 21-12.

(9) *Labour, firewood and chemicals.*

The notes made in Part A, under these headings apply with equal force to this portion of the Arakan scheme.

(10) *Miscellaneous.*

In this instance, the scheme is not so much based on the assumption that Taungya cutting will be stopped or restricted, as on the existence of a surplus quantity of bamboos being available after the Taungya cutters have been supplied with their requirements. Such a stand-point was impossible in the case of the Seik catchment basin, as the area there is comparatively small and the surplus small in proportion. In the Kaladan and Lemru catchments, the area covered with bamboo is very much greater, so that the available surplus must necessarily be far greater than is the case in the smaller area.

There appears to be only one drawback to Akyab as a possible factory site, and that is the question of fresh water. This might possibly be overcome by utilizing water from the tank supplying the town: the supply could be further helped out by preparing storage tanks, a quite feasible proposition when it is taken into consideration that the annual rainfall in this locality is over 200 inches.

POSSIBLE SITES FOR BAMBOO PAPER-PULP MILLS IN THE BOMBAY PRESIDENCY.

Note.—Since these areas were inspected, flowering of the Daugi bamboo has been reported to have taken place but to what extent is not known. This may render some of the areas unworkable for a few years, though the period required for recovery is generally short.

Area No. I. (*See portion marked* **A** *on map.*)

The Gangavalli Catchment Area in the Ankola and Yellapur Ranges of the West and East Kanara Forest Divisions.

(1) *Name and Situation.*

The area is situated on the West Coast of the Bombay Presidency in the Kanara Collectorate and comprises the catchment area of a large river, known as the Gangavalli in its lower reaches, and as the Bedti River where it pierces the Ghats. The valley formed by this river is fairly broad, for a distance of 8 to 10 miles from the coast, and gradually narrows as it approaches the Western Ghats, which lie some 40 miles from its mouth. On its course down the Ghats it passes through narrow gorges and forms a rushing stream, with many small waterfalls. On the plateau it is a narrow stream which in its upper reaches nearly dries up in the hot weather. From the sea to the foot of the Ghats the river is bounded on each side by high spurs and chains of hills jutting out of the Deccan plateau, which gradually disappear on approaching the coast. Small tributaries coming from the surrounding hills flow into the river on either side.

(2) *Description of the forests.*

The forest is what is known as moist deciduous. It contains a great variety of species, intermixed with large quantities of bamboos, of the species known as *Bambusa arundinacea* (Daugi), which, though it occurs nearly all over the area, is especially abundant on the more level ground on each side of the main stream and up the by-valleys. The finest growth is found in the upper limits of the valley round the Ramangulli, Arbail and Shavkar cultivations, and everywhere along the banks of the streams. On the slopes the growth is less luxuriant and the clumps

Pearson.—Utilization of Bamboos in the Manufacture of Paper-pulp.

Photo.-Mechl. & Litho. Dept., Thomason College, Roorkee.

Photo by R. R. Chandilkar, Forest Surveyor.

Bambusa arundinacea Forest, West Kanara Forest Division, Bombay Presidency.

more scattered, being generally denser along the dry rivulets than on the faces of the slopes.

(3) *Area of forest covered by bamboos.*

The area covered by bamboos which can be worked out to the main stream is 68,723 acres, of which 38,643 acres have been classified as first class bamboo area, and 30,080 acres as second class, owing to the relative poorness of the crop. From the map will be seen the general position of the area with reference to the coast-line.

(4) *Species of bamboos and mode of growth.*

The chief species occurring in the area is *Bambusa arundinacea,* a large bamboo, which in the more favourable localities above referred to grows 60 to 80 feet in height and 8 inches mid-girth. In the 2nd class areas it is about 30 feet in length and 6 inches mid-girth.

The number of clumps, obtained by counting six sample plots in 1st class area worked out to 64 per acre, containing a total of 149 new culms under one year old and 306 culms over one year old or a total of 455 culms per acre. These figures are taken into consideration hereafter in calculating the possible yield. A very marked feature in the growth of this species of bamboo is the sheath of the side-shoots, armed with recurved points, resembling thorns, which forms a complete palisade to a height of 6 to 8 feet from the ground round each clump, and which renders extraction more difficult than is the case with the unarmed species.

(5) *Possible factory site.*

The most suitable factory site is at the village of Gumbala situated on the banks of the Gangavalli, above the tidal level, some 14 miles from the sea (see map).

The area, in which the bamboos are most plentiful, starts just above Gumbala and stretches for 24 miles up the valley to the village of Arbail at the foot of the Ghats. The stream is suitable for floating over its entire length, except during the summer months, and possibly during the first two months of the rains. There exists a small Bunder or port on the coast, on a neck of land jutting into the sea, south of the mouth of the river at Tadri, which is a calling place for

Shepherd's steamers. The river at Gumbala is some 200 yards broad, and always contains a plentiful supply of fresh water, while small boats of 5 tons burden can reach it from the sea. It is for this reason, as also from the fact that the place is fairly healthy and open, that it has been chosen as a suitable site for a pulp-mill.

(6) *Outturn.*

The outturn is based on the eight sample plots taken in different parts of the area. The work was carried out by Mr. Miller, the Divisional Forest Officer, his Assistant Mr. Kotwal, and the writer of this report, when the latter was on tour in that District. Owing to the bamboo growth being heavy on the more level ground and lighter on the slopes, it has been considered necessary, for greater accuracy, to divide the forest into two quality areas.

The total area of bamboo-yielding forest is computed at 68,723 acres, the figure having been arrived at by the use of a planimeter. Of this, 38,643 acres are first class and 30,080 acres are second class bamboo forests. Referring to Appendix IV, sample plots Nos. 1 to 6, we get 10,149 lbs. per acre as the average outturn of dry internodes in first class areas, and from sample plots Nos. 7 and 8, 1,975 lbs. per acre in the second class areas. The total gross yield for the whole area, taking into consideration the areas of the two quality classes and their yield per acre, therefore, works out to 451,595,807 lbs. or 201,605 tons. The question as to a suitable rotation on which to cut bamboos has been already discussed in Part II, and has been fixed at 5 years, so that the total sustained yield of dry internodes works out to 40,321 tons per annum. As it will probably be found possible to treat the nodes together with the internodes the annual yield may be raised by 15 per cent.

(7) *Lines of export.*

There are two methods by which the bamboos can be exported (1) by floating down the Gangavalli river and (2) by carting along the Yellapur-Karwar road which runs down the entire length of the valley close to the river. It would be necessary to drag the bamboos to the edge of the river or road, a maximum distance of three miles, but, generally speaking, not one-third of that distance, and afterwards either to float them in rafts down the river or cart them along the road.

It would, however, only be necessary to resort to the latter method in time of high flood or during the summer months.

(8) *Cost of extraction.*

(*i*) *By floating.*—Owing to the thorny palisade above-mentioned, which exists round each clump, the cost of cutting is estimated at Rs. 6 per 100, which is a high figure, the cost of dragging to the river is put at Rs. 3 per 100, and the cost of floating down the river from the centre of the area to Gumbala is put at Rs. 2 per 100, a total of Rs. 11 per 100.

(*ii*) *By carting.*—The average distance is estimated at 12 miles by cart-road. A cart holds 33 bamboos and the rate per cart is 2 annas a mile. This works out to Rs. 6-12 per 100 by cart, to which must be added Rs. 9, the cost of cutting and dragging to the road, which works out to a total of Rs. 15-12 delivered at Gumbala. To this must be added royalty charges. The price of bamboos on the coast is Rs. 10 to 12 per 100, of 20 feet length.

(9) *Cost of landing air-dry internodes per ton at the factory.*

From the results obtained by weighing culms cut in the sample plots (see Appendix IV), we get the following figures :—

Total number of culms cut.	Total weight air-dried, in lbs.	Weight of nodes and saw-dust, in lbs.	Weight of air-dried internodes, in lbs.	Weight of dry internodes per 100 culms, in lbs.	Number of culms required to yield one ton of dry internodes.	Cost of one ton of dry internodes at Gumbala.
554	16,234	2,372	13,862	2,502	89·5 in round figures 90.	Rs. 9-14-5 by floating and Rs. 13-8-0 if carted.

The above calculations are based on a fairly large number of culms cut from various parts of the area, in good, fair and indifferent bamboo forests. The culms were weighed green, and again after the nodes had been cut out and the culms had been allowed to dry for about four months.

(For details see Appendix IV.) The cost of landing dry internodes at Gumbala works out roughly to Rs. 10 per ton, which figure probably could be reduced considerably by working on a large scale and after further experience.

(10) *Labour.*

Part of the cooly labour could be procured from the coast villages, but importation of labour on a fairly extensive scale would be necessary, especially during the harvesting season, when the local population return to their homes to reap the rice crop. The price of labour is 5 to 7 annas a day for men and $2\frac{1}{2}$ to 3 annas for women and children. As regards the artisan class, with the exception of carpenters and a limited number of masons, they would have to be imported.

(11) *Chemicals.*

All chemicals, with the exception of lime, will have to be imported. The cost, however, would not be heavy as they can all be brought by sea and by sailing boats up the river. Large quantities of excellent shell-lime are available on the coast at a cost of 12 annas per cwt.

(12) *Fuel.*

Firewood is plentiful and can be obtained from the area in which the bamboos are found. The price fluctuates considerably, being generally high, owing to the proximity of the Bombay market. The price of coal would be very much the same as in Bombay.

(13) *Miscellaneous facts.*

Climate is an important factor in considering the suitability of a paper-pulp factory site. The upper reaches of the valley are, without doubt, very malarious during the winter months. On the other hand, the coast country and the country as far inland as Gumbala, is healthy, and quite fit for Europeans to live in throughout the year. The supply of meat food is very deficient, though fowls and excellent fish are always procurable.

AREA NO. II. (*See portion marked B on map.*)

The Kala Nadi Catchment Area in the Karwar and Supa Ranges of the West and North Kanara Forest Divisions.

(1) *Name and Situation.*

The area is situated on the West Coast of the Bombay Presidency in the North Kanara Collectorate and consists of the catchment area of a river known as the Kala Nadi, which taps the upper slopes of the Western Ghats and finds its way to the sea at Karwar, the headquarters of the District and a small port, situated in a very fine bay. The valley, formed by this river, is fairly broad and open as far as Kadra, some 20 miles from the sea, and in this area, which is under cultivation, there are relatively few bamboos, except along the banks. Above Kadra the valley gradually narrows in, until above Bobrigadda it forms a ravine, through which the river passes in a deep channel some 100 yards broad. The hills, on each side of the river above Kadra, rise to over 2,000 feet and are clothed throughout with fine high forest. The village of Bobrigadda is about 40 miles from the sea. Above this village, the river, which is still a fine one, passes through the Gund slopes to the foot of the Ghats. The slopes on either side are covered with heavy teak and bamboo forests. The extreme limits, from which it would probably be practicable to exploit bamboos, is 40 miles above Kadra, or a distance of 60 miles from the sea.

(2) *Description of the forests.*

In the lower reaches, especially near the river and up its tributaries, there occur moist deciduous forests, while the greater portion of the lower and middle slopes are covered with dry deciduous forest, containing, above Birkol village, a fair quantity of teak and bamboo forest. The higher slopes are generally covered with evergreen forest, in which no bamboos are found. The prevailing species of bamboo is *Bambusa arundinacea,* known locally as the "Daugi" bamboo. It grows to a large size in the lower areas and is still of fair size on the dry slopes, while, on the Gund plateau above, an area also included in this scheme, it is found growing to a great size. The other bamboos found in these forests are *Dendrocalamus strictus* and *Oxytenanthera monostigma,* of which the former species in particular is not common.

(3) *Area of the forests covered with bamboos.*

The total area in which bamboos are found between Kadra village and the Shivpur Nala, a stretch of the valley covering some 30 miles, is computed to be 20,374 acres. Of this, 14,264 acres are classed as 1st class, and 6,110 acres as 2nd class bamboo forest—the figures based on enumerations made in the Working-Plans. To the above figures must be added the Gund area, which is a continuation of the Kala Nadi forests, in which the Divisional Forest Officer, Mr. Copleston, estimates 7,000 acres to be of the 1st class, giving a total of 27,374 acres of bamboo forest.

(4) *Species of bamboo and mode of growth.*

The common bamboo in these forests is *Bambusa arundinacea*, growing from 60 to 80 feet in height and 8″ mid-girth in the lower parts of the valley and to an even larger size on the Gund slopes, while on the drier slopes it attains a height of 50 feet and 6″ mid-girth. It is found fringing the banks of the main stream throughout its length, and is plentiful on the more level ground, especially near Sulgeri, Birkol, Devkar and above Bobrigadda, as also in Gund, while, on the warmer slopes of the hills, it is found in scattered clumps, being densest up the dry rivulets.

(5) *Possible factory site.*

The best place for a factory would be just above tidal level, on the north bank of the river between Kadra and Balamani villages. Here the river is over 100 yards broad and flows with a strong current throughout the year. Five-ton sailing boats come up daily to Kadra, and from there to the factory would be under two miles, or a total distance of under 24 miles from Karwar harbour. There would be no question of want of water near Balamani, as the river never approaches a state of dryness at any time of the year. There is also plenty of open land on the north side of the river, on which a large mill could be erected.

(6) *Outturn.*

In estimating the outturn of bamboos from these forests, it will be necessary only to consider *Bambusa arundinacea*, as the other two species, *i.e.*, *Oxytenanthera monostigma* and *Dendrocalamus strictus* are not found in sufficient quantities to justify their inclusion in the estimate.

The conditions in this valley are identical with those in the neighbouring Ankola valley, which have been discussed above, so that the figures obtained by enumerating sample plots in that area will be applied here also. The growth in the Gund area being considered superior to that in the Kala Nudi or Gangavalli valleys, separate enumerations have been carried out, with a view to obtaining more reliable results.

The area of 1st class bamboo forest in the valley proper is 14,264 acres, while the outturn, according to figures given in Appendix IV, show a yield of 10,149 lbs. per acre, or a total outturn of 144,765,336 lbs. or 64,627 tons.

The 2nd class area in the valley covers 6,110 acres. From Appendix IV, we see that the yield per acre in this class of forest is 1,975 lbs. per acre or a total yield of 12,067,250 lbs. or 5,387 tons.

In the Gund plateau there are 7,000 acres of 1st class forest. From the figures of the enumerations of five sample plots (see Appendix IV), it will be seen that the yield of dry internodes per acre is 28,968 lbs, giving a total yield of 202,776,000 lbs. or 90,520 tons.

Therefore the gross yield stands as follows :—

	Tons.
1st class area in valley	64,627
2nd class ,, ,, ...	5,387
Gund area	90,520
	160,534

As has been explained in Part II, the rotation is fixed at five years so that the sustained yield works out to 32,107 tons of dry internodes per annum. As explained under (6) Outturn, page 78, this estimate would be raised by 15 per cent. by including the nodes.

(7) *Lines of export.*

The Kala Nadi river is a broad stream which drains the whole area. Floating is possible from September to March and even later, as water flows in the channel throughout the year. Owing, however, to rapids above Kadra and again below Bobrigadda, floating is difficult unless the supply of water is considerable. In the case of the valley forests, the distance, from which bamboo will have to be dragged to the stream, never

exceeds two miles, while in most cases it will not be half that distance. In the case of the bamboos to be procured from the Gund plateau, which lies in the upper reaches of the river, they will have to be dragged a maximum distance of three miles to the edge of the plateau and then be slid down the steep sides of the Ghats to the river bank. There also exists a very fair road suitable for carts on the right bank of the stream from Kadra to Sulgeri, which is to be extended to Bobrigadda. The question of extraction, provided cooly labour is available, presents no serious difficulties.

(8) *Cost of cutting and extraction.*

As before stated, the extraction of the culms is rendered difficult owing to the palisade of thorns round the base of the clumps. The cost of cutting 100 culms is therefore put at Rs. 6 throughout. The cost of dragging to the river, a maximum distance of two miles, is put at Rs. 2 for the valley forests and Rs. 4 from Gund, while the cost of floating 100 bamboos from the centre of the area near Bobrigadda would be Rs. 2 and from Gund Rs. 5. The total cost of extraction, therefore, works out to Rs. 10 from the valley and Rs. 15 per 100 from Gund. The market rate for bamboos at Karwar, including royalty, is Rs. 10 to Rs. 14 per 100, according to quality.

(9) *Cost of landing air-dried internodes per ton at the factory site.*

The figures for the valley forests are taken from paragraph 9, page 79, of the Ankola valley scheme, and as the cost of landing green bamboos at Balamani is Rs. 10, the cost of delivery of the dry internodes at the factory site, obtained from the valley forests, works out at Rs. 9 per ton. Separate figures for Gund are given in Appendix IV. The internodes from one bamboo weigh 68 lbs, therefore the number of bamboos required to make a ton of air-dried tubes is in round figures 33, the cost of landing which at the factory site comes to Rs 4-15-2. The reason why it is cheaper to deliver one ton of air-dried internodes from the further area is that the individual culms from that area (Gund) are much larger and heavier than those found in the valley forests, while the actual labour required for their extraction is not in proportion to their size owing to the facility of floating them down the river.

(10) *Labour.*

No great number of coolies is available in the neighbourhood, as the coolies, who are in the habit of working in the forests, are employed in working the fuel coupes. It would, therefore, be necessary to import labour from Goa territory, Ratnagiri District and Savantwadi State. Cooly wages are from 4 to 7 annas a day, according to the season of the year, and women and children can earn $2\frac{1}{2}$ to 3 annas a day. Carpenters and masons demand 12 annas to Re. 1 per day.

(11) *Chemicals.*

All chemicals, with the exception of lime, will have to be imported, though the cost of doing so will not be heavy, as they can be brought by sea to Karwar in steamers and in sailing boats of three to five-ton burden up the river as far as Kadra. Large quantities of excellent shell-lime are procurable on the coast, at a cost of 12 annas per cwt.

(12) *Firewood.*

Firewood is available in fair quantities, but it would not be sufficient to run a large mill. Coal would have to be imported, the price being about the same as in Bombay. The price of fuel is high, as much as Rs. 10 to 12 per ton, owing to the facility of export by sea to Bombay.

(13) *Miscellaneous facts.*

The climate in this valley is, on the whole better than in the neighbouring valley of Ankola, for which a scheme has been prepared in the foregoing pages. The climate in and around the proposed factory sites in both areas is about the same, but the upper reaches of the Ankola valley compare unfavourably with those of the Kala Nadi. A small port is situated at the mouth of the river at Kodibag, from which timber is exported up and down the coast. In the monsoon months the entrance is dangerous for ships, owing to the bar. The harbour is within two miles of Karwar, the headquarters of the North Kanara Collectorate, which is considered a healthy place for the West Coast.

Area No. III. (*See portion marked* **C** *on map.*)

The Mungod Forests of the East Kanara Forest Division.

(1) *Name and Situation.*

The area is situated on the Deccan plateau, stretching from the edge of the Western Ghats inland for a distance of above 20 miles. It is situated in the Yellapur and Mungod Ranges of the East Kanara Forest Division of the North Kanara Collectorate. The configuration of the land is characterised by an undulating plain, which is cut into by small rivulets, the southern portion being the upper catchment area of a river, known in its upper reaches as the Bedti and as the Gangavalli as it approaches the sea. The northern portion of the area is tapped by the Kala Nadi which runs more or less parallel to the Gangavalli, and finds an outlet into the sea at Karwar (see map).

(2) *Description of the forests.*

The area is covered with dry deciduous forests, while, here and there along the rivulets and on low-lying areas, evergreens occur. It is well stocked with trees and bamboos are found everywhere.

(3) *Area of the forests covered with bamboos.*

The whole area consists of bamboo forest of a practically uniform type. It has been divided into five blocks in the Working-Plan, of which the portions contemplated in this scheme are as follows :—

Block No.	Acres.
XIII	25,000
XIV	20,000
XV	21,000
XVI	8,000
XVIII (part)	5,000
XXIII (part)	34,000
Total	113,000

As the growth of the bamboos is fairly uniform throughout, the whole area has been grouped into one quality class.

(4) *Species of bamboos and mode of growth.*

The common bamboo in these forests is *Bambusa arundinacea,* which grows from 40 to 50 feet in height and 8″ mid-girth (see Appendix V). Portions of the area are densely stocked with this species and it is everywhere plentiful. It is not extracted to any great extent, the number taken out in 1908-09 being 14,500 only. The other bamboo found is *Dendrocalamus strictus* which, as compared with *Bambusa arundinacea,* is not plentiful, though fully sufficient to meet the local market.

(5) *Possible factory site.*

There are two possible factory sites. One is at Bomanhalli, also known as Kegdal, which is situated some five miles from the north-western limits of the area, on the Kala Nadi river. From the bamboo forest and leading to this place are several good cart-roads, while from the proposed factory site to Alnavar, a station on the Madras and Southern Mahratta Railway, is a high road, the distance being 26 miles. A plentiful supply of good water is found throughout the year in the Kala Nadi at Bomanhalli, so that, in many ways, the place is suitable for a factory site. The disadvantages are that it is out of the way and that though it is close to the bamboo forests, the distance over which supplies, chemicals and coal would have to be carted, is not only considerable but might present serious difficulties during the rains.

The other possible site is Hubli, a station on the Madras and Southern Mahratta Railway, an average distance of 35 miles from the centre of the forests. Three main roads, running through the area, go to Hubli, the gradients over their entire length being in no case excessive or long, as the country is everywhere practically flat. This place has several advantages over the Bomanhalli site. Hubli is a fairly large station, and also has a good climate, besides which, chemicals, coal and labour would be far more easily procurable.

(6) *Outturn.*

The outturn is based on *Bambusa arundinacea* only, as the other species are not plentiful, besides being already in considerable demand. Five sample plots were taken by Mr. Butterworth, Assistant Conservator of Forests, in blocks XIV and XV (see Appendix V) giving a yield of

5,461 lbs. of dry internodes per acre. The area of the forests is 113,600 acres, so that the total yield works out to 617,420,660 lbs. or 275,143 tons. By cutting over the area in five years the sustained yield works out to 55,028 tons of dry internodes per annum. The total may be raised 15 per cent. if the nodes are taken into account.

(7) *Lines of export.*

(*i*) *To Bomanhalli.*—The area is well supplied with roads. The Alnawar-Kadra main road runs through Bomanhalli. Block XIII is tapped by the Yellapur main road, 13 miles being the distance from the centre of the area to the factory site. Blocks XIV and XV are tapped by feeder roads, giving on to main road, a distance of 15 miles from Bomanhalli. The bamboos in blocks XVI, XVIII and XXIII will have to be carted over the Yellapur-Alnawar main roads, an average distance of 31 miles.

(*ii*) *To Hubli.*—Were Hubli taken as the site for the factory, the bamboos from blocks XIII, XIV and XV would have to be carted over the Yellapur-Hubli main road, a distance of 30 miles; those from blocks XVI, XVIII and XXIII by the Sirsi-Hubli main road, a distance of 40 miles.

The average distance of carting, therefore, works out to 18 miles in the case of Bomanhalli and 35 miles in the case of Hubli.

(8) *Cost of cutting and extraction.*

The cost of cutting 100 bamboos is put at Rs. 5, that is, one rupee less than was the case below the Ghats. The reason for this is that the culms are not so large in this locality as they are in the Karwar and Ankola forests. A cart can take 1,200 lbs. of bamboos. One hundred dry bamboos weigh 3,720 lbs. (see Appendix V), therefore 100 bamboos furnish three cart-loads. The cost of carting is 2½ annas per mile, therefore the cost of carting 100 dry bamboos to Bomanhalli, an average distance of 18 miles, comes to Rs. 8-7 and to Hubli, an average distance of 35 miles, Rs. 16-6 per 100.

(9) *Cost of landing air-dried internodes per ton at the factory site.*

The cost of landing dry internodes at Bomanhalli, therefore, works out to Rs. 8-6 per ton and at Hubli at Rs. 13-1 per ton. Were the nodes to be taken into account, the rate would be reduced by 15 per cent.

(10) *Labour.*

Cooly labour will undoubtedly be a difficulty in this locality. It is obtainable, in limited quantities, at 5 to 7 annas a day for men and $2\frac{1}{2}$ to 3 annas for women, who, in these parts, are hardworking. It would undoubtedly be necessary to import labour either from the coast or from the neighbouring Deccan districts.

(11) *Chemicals.*

Good limestone rock occurs at Churanhukli about 12 miles north-west of Yellapur and about 15 miles from Bomanhalli. Shell-lime is also procurable in large quantities on the coast at a distance of 70 miles. The other necessary chemicals will have to be imported.

(12) *Firewood.*

Fairly large quantities of fuel are always available from these forests and would contribute largely to supply a mill at Bomanhalli. At Hubli it would be necessary to use coal.

(13) *Miscellaneous facts.*

Most of the roads in this locality are metalled, and therefore extraction by cart is possible practically throughout the year. This is not the case when floating is employed as in the Gangavalli and Kala Nadi areas, where the rivers are low in April and May.

The climate of this tract of forest is, on the whole, better than in the two previous areas dealt with, while, as far as the factory sites are concerned, Hubli is preferable to Bomanhalli in this respect. The difficulty will be in obtaining sufficient labour, to which point careful attention will have to be paid before any steps are taken to establish a mill.

POSSIBLE SITES FOR BAMBOO PAPER-PULP MILLS IN THE MADRAS PRESIDENCY.

Area No. I. (*See portions marked **D** on map.*)

The Uppinangadi and Puttur bamboo areas in the South Canara Forest Division of the Madras Presidency.

(1) *Name and Situation.*

These forests are situated in the Uppinangadi Taluka of the South Canara Collectorate, some 60 miles inland from Mangalore, and a few miles short of the foot of the Western Ghats. The distance from the centre of the area to the sea is 60 miles. Down the Netravati river to Panimangalore is 40 miles, to which place sailing boats of five tons burden ply daily from Mangalore. The forests are drained in the north and centre by the Netravati river and its tributaries, the Kumardhari and by the Payaswani river in the Puttur Range. (See map.)

(2) *Description of the forests.*

The areas included in this scheme contain moist and dry deciduous forests with patches of evergreen, and are not dissimilar in character to those found in the neighbouring forests of North Kanara in the Bombay Presidency. In places the bamboo growth is not heavy but, in others, especially along small water-courses and in depressions, it is extremely fine and luxuriant.

(3) *Areas of forests covered with bamboos.*

The areas directly taken into consideration in this scheme lie in the Uppinangadi and Puttur Ranges, though mention will hereafter be made of other areas which might also be added and from which raw material could be obtained. The forests now under consideration are made up

of 15 blocks, most of which have no connection one with another, being divided from each other by narrow strips of revenue land.

Range	Blocks.	Area in acres.	
Uppinangadi Range.	1. Nerinkamale	3,894	
	2. Porkala	4,558	
	3. Shibage	3,456	
	4. Kadambila	1,848	
	5. Konage	6,642	
	6. Padnur	3,900	
			24,298 acres
Puttur Range.	7. Sampaji	5,120	
	8. Pumale	960	
	9. Purappa	1,920	
	10. Kankamajulu	640	
	11. Jalsur W.	960	
	12. Jalsur E.	160	
	13. Anegundi	640	
	14. Kaniarmale	500	
	15. Denachalla	600	
			11,500 acres.
		Total	35,798 acres.

(4) *Species of bamboo and mode of growth.*

By far the greater portion of the bamboo forest consists of *Bambusa arundinacea*, which, on the upper slopes of the low hills, is found growing 30 to 40 feet in height, while in the moister and lower areas it grows 70 to 80 feet in height, with a mean mid-girth of 8″. The Working-Plan Officer enumerated 426 acres in the various blocks which go to form the Uppinangadi Range and found 12·8 clumps of bamboo per acre, averaging 10 culms per clump. *Dendrocalamus strictus* bamboo also occurs in the forests, but only in small quantities.

(5) *Possible factory site.*

The most suitable site for a mill would be Panimangalore on the Netravati river (see map). Another possible site would be Mangalore, on the sea, but fuel and labour are more expensive at that port than further up the river. As regards water, a plentiful supply is available throughout the year from the river at Panimangalore.

(6) *Outturn.*

Mr. Foulkes, the Working-Plan Officer, when making the Working-Plan for these forests, enumerated bamboos over 426 acres, by taking sample plots scattered over each block. In these enumerations, he counted all the bamboo clumps in the area, but did not count the number of culms per clump, which has been put at the low estimate of 10 culms per clump. Based on these figures, which should be a very fair guide, the following calculation has been made :—

Name of Range.	Name of block	Area in acres.	Average area of sample plot taken by the Working-Plan Officer, in acres.	Average number of clumps per acre.	Number of bamboos in the whole area, taking 10 culms per clump.
Uppinangadi.	Nerinkemale .	3,894	101 7	12·07	467 280
	Porkala . .	4,558	121·1	10·92	501,380
	Shibage . .	3,456	82·6	16·95	584,064
	Kadambila . .	1,848	35·0	5·74	105,336
	Konage . .	6,642	86·0	13·35	883,386
	Padnur . .	3,900	*Nil*	10·0*	390,000
Puttur.	Sampaji . .	5,120	Do.	12·0	614,400
	Pumale . .	960	Do.	10·0	96,000
	Purappa . .	1,920	Do.	8*	153,600
	Kankamajulu .	640	Do.	8*	51,200
	Jalsur W. . .	960	Do.	8*	76,800
	Jalsur E.. . .	160	Do.	8*	12,800
	Anegundi . .	640	Do.	6*	38,400
	Kaniarmale . .	500	Do.	8*	40,000
	Denaehalla . .	600	Do.	8*	48,000
		35,798	426·4	*Estimated	4,062,646

Working on a five-year rotation we arrive at a sustained annual yield of 812,629 bamboos.

Now, from the enumeration of a sample plot in Nerankimale (see Appendix VI), the yield from 140 culms found on one acre was 6, 550 lbs. of dry internodes or, in round figures, 47 lbs. per culm. The annual sustained yield of dry internodes working on a five-year rotation, therefore, works out at 38,193,563 lbs. or 17,051 tons.

It was mentioned elsewhere that other areas might be tapped to supply the factory at Panimangalore with bamboos. Mr. Barry, the Divisional Forest Officer, suggests that bamboos could be floated down the Paishwani river, from the forests it drains, to Kasargad, be railed to Mangalore and taken up the Netravati river to Panimangalore. Were the erection of a mill contemplated at this spot, the possibility of utilizing this source of supply also would have to be duly considered.

(7) *Lines of export.*

A metalled road runs from Mangalore to Manjrabad, passing through the Uppinangadi range and taps the six blocks under consideration, while the Bisli Ghat road runs on the south side of the Padnur block. The average distance over which bamboos would have to be carted to Valol, on the Netravati river, is 15 miles, and the distance over which they will have to be floated from Valol to Panimangalore is 20 miles.

There are two possible ways of exploiting the bamboos from the nine blocks in the Puttur Range. One is by carting them down the Mangalore-Mercara main road and by the Jalsur-Subramania road, an average distance of 40 miles, the other by floating them down the Kumardhari river *via* Uppinangadi to Panimangalore. The river, however, is bad for floating, being full of rapids and boulders. The only way of improving it would be by carrying out fairly extensive blasting operations and by erecting temporary dams, so as to regulate and train the stream. Some three miles above the junction of the Netravati and Kumardhari rivers at Uppinangadi, there is, on the latter river, a low waterfall, which was inspected with a view to ascertain the possibility of utilizing the water-power and finding out if it formed an obstruction to possible floating operations. The river here is very broad, so that extensive works would have to be carried out to utilize the water for power, while it was found that the main channel was sufficiently broad to allow of rafting operations being carried out.

The river from Uppinangadi to Panimangalore is also full of boulders and shallows, though, no real difficulties occur to prevent floating from September to the end of January. After January, the river runs low and rafts containing over 40 bamboos are difficult to manage.

(8) *Cost of cutting and extraction.*

The cost of cutting and exploiting 100 bamboos from the Uppinangadi forests to Panimangalore works out as follows :—

	R.	a.	p.
1. Cost of cutting 100 bamboos	6	0	0
2. ,, ,, dragging to road	2	0	0
3. ,, ,, carting 15 miles to Valol at 2 annas a mile for 3 carts containing 33 bamboos each . . .	5	10	0
4. ,, ,, toll on 3 carts at 4 annas each . . .	0	12	0
5. ,, ,, floating from Valol to Panimangalore . .	2	0	0
	16	6	0

The cost of exploting 100 bamboos from the Puttur Range works out as follows :—

	.	a.	p.
1. Cost of cutting 100 bamboos	6	0	0
2. ,, ,, dragging to road	2	0	0
3. ,, ,, carting 40 miles at 2 annas per mile taking 33 bamboos and including toll	15	12	0
	23	12	0

The weight of 100 air-dried bamboos is 5,803 lbs. (see Appendix VI), so that the cost of landing one ton of air-dried bamboos at Panimangalore from the Uppinangadi forest comes to Rs. 6-6 and from the Puttur forests Rs. 9-4 per ton.

(9) *Cost of landing air-dried internodes per ton at factory site.*

From Appendix VI, it will be seen that the dry nodes are, in round figures, 20 per cent. by weight of the entire culms, so that the cost of landing dry internodes from Uppinangadi at Panimangalore works out at Rs. 7-10-6 and from Puttur at Rs. 11-13 per ton. On the other hand, if the nodes are also utilized, these figures must be reduced by 20 per cent. for this locality.

(10) *Labour.*

Cooly labour is fairly plentiful, though some may have to be imported for working in the mill. The wages earned by men are from 4 to 6 annas per day and women $2\frac{1}{2}$ to 3 annas. Good carpenters and masons are available in Mangalore at 12 annas to Re 1 a day. Carts are fairly plentiful but, were bamboos to be carted in large quantities from the Puttur forests, more carts would have to be introduced.

(11) *Firewood.*

Firewood is very plentiful in these forests, and the demand comparatively small. Its price is from Rs. 3 to Rs. 4 per ton at Uppinangadi and Rs. 6 per ton at Panimangalore.

(12) *Chemicals.*

Shell-lime is available in large quantities on the coast: it is sold in bags of 160 lbs. each, and the price of 100 such bags is Rs. 28.

The Bombay Steam Navigation Company's steamers call at the port of Mangalore, so that the cost of importing the necessary supplies, chemicals and fuel by sea should not be excessive. The terminus of the Madras Railway is situated at Mangalore, by which chemicals could be imported when steamer traffic is stopped during the monsoon.

(13) *Miscellaneous facts.*

The site chosen for the factory at Panimangalore is, generally speaking, a healthy one, the country being open and flat. The forests from which the bamboos can be exploited are feverish just after the rains. The coast rivers are, generally speaking, more silted up in this district than is the case in North Kanara, which is probably due to the excessive denudation of all tree-growth on the waste lands. For this reason, the streams are shallower, rendering navigation more difficult, and at the same time, rendering the rivers more liable to excessive floods in the monsoon.

AREA NO. II. (*See portion marked E on map.*)

The Kanoth bamboo forests of the North Malabar Forest Division of the Madras Presidency.

(1) *Name and Situation.*

These forests are situated in the Kottayam Taluka of the Malabar Collectorate, some 20 miles inland from the seaport of Tellicherry and directly below the Wynaad forests of the Western Ghats. To the south of the bamboo area runs a small stream, known as the Edayer, the northern limit being the Tellicherry-Manantoddy high road.

(2) *Description of the forests.*

The area covered with bamboos is extremely limited, so that, were a mill to be erected and supplied from this area, it would necessarily have to be run on a small scale. The forests containing the bamboos lie in the valley of the Edayer (see map) and though forests extend up the range of hills to the south, and also cover the Western Ghats to the east, they contain but few bamboos. On the more level ground, to the south of the main road and extending up the valley to Nedumboil Chuttram, the bamboo growth is in many places extremely fine, and some of the culms exceed in size and weight any stems of this species weighed elsewere.

(3) *Area of forest covered with bamboos.*

The total area of the block is 19,018 acres ; of this, the forests lying in the valley cover some 3,000 acres and are densely stocked with bamboos. The rest of the area contains semi-moist-deciduous forest, in which bamboos occur, but only scattered here and there in small quantities.

(4) *Species of bamboos and mode of growth.*

The prevailing species is *Bambusa arundinacea* and therefore the same as that prevailing throughout the entire length of the Western Ghats. It forms in these forests very fine clumps, containing many large culms. The average length of 200 cut stems was 56½ feet and 10·7″ mid-girth, representing a length of about 10 feet and a girth of 2″ in excess of any

previously recorded. The other species found in these forests is *Dendrocalamus strictus*, a small strong bamboo, the demand for which in the market is already equal to, if not greater than, the possible outturn, so that from the point of view of pulp-making it may be neglected. There exists to the south of the main road, and some three miles from the Travellers' Bungalow, a bamboo plantation in which several exotics, chiefly from Burma, have been introduced and which have done remarkably well. The area of the plantation is, however, of insufficient size, to be of any real importance, except to demonstrate the possibility of cultivating such species in this locality.

(5) *Possible factory site.*

It is not easy to fix on a suitable site for a factory. The best place would probably be above the village of Kuttaparamba, in the Edayer creek, at a point a little above that at which the tide makes itself felt. To ensure a sufficient supply of fresh water for the mill, it would be necessary either to dam the river or prepare storage tanks, otherwise there would be insufficient water from February onwards till the monsoon sets in. The distance of the proposed site is 12 miles from the centre of the bamboo area and 8 from the Railway station of Tellicherry, both places being on the Tellicherry-Manantoddy high road, which also passes through the bamboo area. The proposed site is by no means an ideal one, though the best which could be found.

(6) *Outturn.*

The area from which bamboos can be exploited is small, though this defect is in a measure compensated for by the heavy crop. From Appendix VI, it will be seen that the average outturn of dry internodes is 29,909 lbs. per acre or 13·3 tons, which gives a gross yield of 39,900 tons, or by cutting on a five-year rotation a sustained yield of 7,980 tons of dry internodes per annum. In the above calculation, only the area which is densely covered with bamboos has been taken into account, so that the figure of sustained yield, which might be augmented by fellings in the other portions of the block, may be taken as a low estimate.

(7) *Lines of export.*

A small river, named the Edayer, which is about 20 yards broad at Kanoth, runs down the south boundary of the bamboo area. Along the

north side, running the whole length of the area, is the Tellicherry-Manantoddy metalled road. Along this road, the gradients, within and below the bamboo area, are nowhere steep, so that loaded carts can be moved along it without difficulty. The stream is not really suitable for floating bamboos, though it could be utilized for the purpose during the months of August, September and October. The Southern India Railway runs through Tellicherry, northwards along the coast to Mangalore and southwards to Calicut.

(8) *Cost of cutting and extraction.*

It has been mentioned above that bamboos will have to be transported from the forest to the mill by carts. They will also have to be dragged from the forest to the road, a distance which will rarely exceed a mile. Under these conditions the cost of landing air-dried bamboos, from the centre of the area to Kuttaparamba, works out as follows :—

	R.	a.	p.
1. Cost of cutting 100 bamboos	6	0	0
2. ,, ,, carting at 4 annas per mile, over 12 miles, and 20 bamboos per cart	15	0	0
3. ,, ,, dragging to road	2	0	0
TOTAL	23	0	0

The reason why the estimated number of bamboos per cart has been put as low as 20 is that the average dry bamboo with nodes weighs as much as 63 lbs. so that 20 weigh about ½ ton which is the capacity of cart over a good road.

(9) *Cost of landing air-dried internodes per ton at the factory site.*

From Appendix VI it will be seen that the dry nodes make up 16 per cent. of the total weight of a dry. bamboo. Now the average weight of 100 air-dried bamboos is 6,370 lbs. or 63·7 lbs. per bamboo, of which 10·2 lbs. is the weight of the nodes. It, therefore, takes 42 bamboos to make up one ton of dry internodes. It costs Rs. 23 to land 100 such bamboos at the mill, so that one ton of dry internodes will cost Rs. 9-10-6 per ton at Kuttaparamba.

(10) *Labour.*

Cooly labour is not available in large quantities, and will certainly have to be imported from the coast villages. The usual wages for men is 4 to 6 annas per day, according to the season. Skilled labour, such as carpenters and masons, is available from Tellicherry, failing which it could be procured from Mangalore or Calicut. The supply of carts is also insufficient and will have to be augmented by supplies from other parts.

(11) *Firewood.*

Firewood is available in considerable quantities from the neghbouring forests and possibly from the Ghat forests above the bamboo area, though the labour to collect it and the carts with which to transport it to the mill will not be sufficient unless more are introduced into the district. Coal is available on the railway, though its price is high, the area being far from the coal-fields. The question of fuel is therefore one which will require careful attention.

(12) *Chemicals.*

Shell-lime is procurable on the coast at about 12 annas per cwt. The other chemicals can be imported cheaply by sea or failing that line of supply in the monsoon, they can be railed to Tellicherry and carted to the mill, a distance of 8 miles.

(13) *Miscellaneous facts.*

The site selected for the factory is not unhealthy. The difficulty does not appear to lie in this direction but in the labour question, the cost of fuel and possibly the water-supply, all of which points will require careful consideration before coming to any decision as to the advisability of erecting a pulp-mill in this locality.

AREA No. III. (*See portions marked **F** on the map.*)

The Nilambur and Amarampalam Bamboo areas of the South Malabar Forest Division of the Madras Presidency.

(1) *Name and Situation.*

These forests are situated in the Nilambur and Amarampalam Ranges of the South Malabar Division, in the open valley formed by the Chaliar

river and its tributaries, some 50 miles from the sea and stretching 8 to 9 miles above the village of Nilambur. The river Chaliar finds its way from the slope of the Nilgiris, passing in its upper reaches through the bamboo and teak forests above mentioned, to the sea at Calicut.

(2) *Description of the forests.*

The forest areas lie on the slightly undulating ground to the north of the Chaliar river (see map) and comprise moist-deciduous forest, in which extensive clearings have been made and on which has been created the famous Nilambur teak plantation. The growth of bamboos, where such clearings have not been carried out, is generally dense, the culms being often of enormous size. To the south of the river lie private forests, also well stocked with bamboos.

(3) *Area of forest covered with bamboos.*

In computing the area covered with bamboos, those covered with plantations have not been taken into account. Though no enumeration was made in the Private Forests to the south of the river, they may also be taken into account in this scheme, as it is understood that they would also be available for the supply of bamboos.

The following figures of areas have been taken from the Working-Plan prepared for these forests :—

	Name of Block.	Area.	
Nilambur Range	Vellachapally	623 acres.	
	Pokode	508 ,,	
	Kanakutha	668 ,,	
	Chattawbaria	215 ,,	
	Valluvasheri	204 ,,	
	Panayangote	..	
	Eranbaden	282 ,,	
	Eddakode	580 ,,	
			3,080 acres.
Amarampalam Range	Kallikutta	..	
	New Amarampalam	2,500 acres.	
	Private Forests	3,800 ,,	
			6,300 acres.
	GRAND TOTAL		9,380 acres.

(4) *Species of bamboos and mode of growth.*

The species is the same as elsewhere on the West Coast, being *Bambusa arundinacea*, the culms of which are large and many of which go to form a clump. In the first seven blocks mentioned in the above list, the bamboo growth is dense, while the forests of the Amarampalam Range and the Private Forests to the south of the river, are fairly well stocked with bamboos. The palisade of thorny branches, of which mention has been made elsewhere, is even heavier round the clumps in these forests than is the case in the forests of North Malabar and in Kanara.

(5) *Possible factory site.*

The most suitable factory site is probably near the village of Chaliapuram, situated on the Chaliar river, 24 miles from the sea, and above tidal level. The longest line, along which floating from the reserves would have to be carried out, is 26 miles. Chaliapuram has the advantage of being so situated that five-ton sailing boats can reach it from Calicut at all times of the year, that the bamboos can be floated down without difficulty to the mill from the forest, and that there is a plentiful supply of fresh water available. Were the mill to be erected at Calicut, which is more central and on the railway and also a seaport there might be difficulty in obtaining a sufficient supply of fresh water. It is true that the cost of importing the chemicals might be reduced by placing the mill at the seaport of Calicut, but, on the other hand, the cost of transporting them to Chaliapuram in sailing boats would be relatively small.

(6) *Outturn.*

The possible outturn is based on the enumerations made in these forests (see Appendix VI). Owing to the limited time available, only two sample plots were taken, so that, for the forests in the Amarampalam Range and in the Private Forests, which were inspected and found to contain rather less bamboos than in the forests where enumerations were made, a 20 per cent. reduction has been adopted. The average outturn of dry internodes is 25,544 lbs. or 11·4 tons per acre. The area of the fully-stocked bamboo forest is 3,080 acres and that of fairly-stocked forest, to be calculated on a 20 per cent. reduction or at 9·1 tons per acre. is 6,300 acres. The gross yield of dry internodes, therefore, works out for

both areas together, at 92,442 tons. Cutting on a five-year rotation, the sustained supply of air-dried internodes comes to 18,488 tons per annum. These figures, as elsewhere explained, may be raised by 16 per cent. if the nodes are taken into account.

(7) *Lines of export.*

Bamboos can be floated down the main stream of the Chaliar river throughout the year, and down its tributaries from July to November. The longest distance over which floating will have to be carried out from the forests of Nilambur and the Private Forests, to a mill at Chaliapuram, is 26 miles.

From the forests of the Amarampalam Range, the bamboos will have to be floated down the Karimpoya river and its tributaries, the former being a large tributary of the Chaliar river, the junction of the two streams occurring just above the village of Nilambur. Floating is possible down one tributary of the Karimpoya from as far up as the village of Nedamgam and also from up another tributary of the same river to Nellinkutta, so that the extreme distance, over which bamboos would have to be dragged or carted from the forests of Amarampalam to a floating stream, would be 4 to 5 miles. From that point, they can be floated down to the proposed mill site without difficulty.

The Chaliar river is also available as a means of communication with Calicut as sailing boats come up to Chaliapuram throughout the year. Calicut is also a seaport and at Kalai, 3 miles from Calicut, exists a station of the South Indian Railway, close to a navigable branch of the river.

(8) *Cost of cutting and extraction.*

The cost of felling and extraction from the Nilambur and Private Forests works out as follows :—

	R.	*a.*	*p.*
1. Cost of cutting 100 bamboos	6	0	0
2 ,, ,, dragging to floating stream, an average distance of one mile	2	0	0
3. ,, ,, floating to factory site	2	0	0
	10	0	0

Cost of extraction from the forests of the Amarampalam Range:—

	R	a.	p.
1. Cost of cutting 100 bamboos	6	0	0
2. ,, ,, carting or dragging 5 miles to a floating stream, a cart taking 20 bamboos, at 4 annas per mile . . .	6	4	0
3. ,, ,, floating 30 miles to mill	2	12	0
	15	0	0

(9) *Cost of landing air-dried internodes per ton at the factory site.*

From Appendix VI, it will be seen that the dry nodes make up, in round figures, 14 per cent. of the dry culms. To this figure 2 per cent. should be added for loss in sawing, or a total of 16 per cent. should be deducted from the total weight of the bamboos in order to arrive at the weight of the dry internodes. From the same statement it will be seen that a dry culm weighs 72 lbs. or after deducting the weight of the nodes 60·5 lbs. It therefore requires 37 culms to produce a ton of air-dried internodes. The cost of landing one ton of dry internodes at the mill site, therefore, works out to Rs. 3-11-2 per ton from the Nilambur and Private Forests and Rs. 5-8-10 per ton from the forests of the Amarampalam Range. Provided the nodes are also treated, the cost of extraction would be reduced by 16 per cent.

(10) *Labour.*

Cooly labour is fairly plentiful along the coast and could be imported at 6 annas per day. Carts cost 4 annas per mile and will carry up to 6 cwts. Masons and carpenters are available in Calicut at about Re. 1 per day. The same labour difficulties, which were anticipated in the case of Kanoth, should not occur in Nilambur.

(11) *Firewood.*

Firewood is fairly plentiful at Nilambur and, it is estimated, would cost Rs. 4 to Rs. 5 per ton at Chaliapuram, exclusive of royalty. The yield is roughly estimated at 2,000 tons per annum.

(12) *Chemicals.*

Shell-lime is available in fairly large quantities along the coast, and costs about Rs. 13 per ton or Rs 14 per ton at the mill. The other

chemicals necessary would have to be imported by sea, their prices at Calicut and Bombay being approximately the same, if imported from Europe.

(13) *Miscellaneous facts.*

The place proposed for the mill is a healthy spot as compared with many similar localities on the West Coast. Nilambur has also not a bad reputation, it being the head-quarters of the Divisional Forest Officer of South Malabar. The proposed mill site presents several advantages over the other places, which have been dealt with in Madras, in that, it lies on a large river, so that not only can bamboos be floated down during the greater part of the year, but also it is in direct communication by sea and railwith the outside world.

PART V—PLANT.

COST OF PLANT REQUIRED FOR A MILL.

It is not possible, for want of space, to give more than one or two estimates of cost of plant, and those given are only intended to show approximately what it would cost to erect a large pulp-mill. Those interested in the subject will no doubt obtain their estimates after having decided on the proposed capacity of the mill.

Sindall's estimate for a mill.—Mr. R. W. Sindall in his booklet on "Bamboos for paper-making" of 1909 (Marchant, Singer & Co., 47, St. Mary Axe, E. C., London) gives the cost of a mill with a weekly output of 200 tons of bleached bamboo-pulp, working with caustic soda, as follows :—

	£
Estimated approximate cost of plant	20,000
Buildings and foundations	12,000
Contingencies	4,000
Total .	36,000

James Bertram & Sons' estimate for a mill.—Various estimates by firms in England and America are available. The following is one kindly sent by James Bertram & Sons, Limited, of Leith Walk, Edinburgh.

A mill is designed to produce about 20 tons of air-dried unbleached bamboo-pulp per day of 24 hours, working by the soda process.

Approximate cost of the machinery, all delivered f. o. b. Glasgow, £15,500 including steam and power plant. Approximate weight 600 tons ; to the above estimate will have to be added cost of buildings, etc., which will vary according to the locality in which they are erected.

Estimate put up by Lounsbery Bros. of Chicago.—Another estimate is available from America, which was sent by Lounsbery Bros. & Co., of 305, Dearborn St., Chicago. The estimate, which was made in dollars,

has been converted into pounds sterling. The figures for a Soda-Pulp-Mill estimated to turn out 10 tons of bleached pulp per 24 hours are :—

	£
Buildings	5,800
Add—10 per cent. . . .	580
	6,380

Equipment.

	£
Power House plant	3,900
Boiler ,, ,, ...	1,400
Wood Preparing room	220
Digester Building room	1,700
Pulp Washing	1,420
Screen and Wet Machine room	1,140
Incinerator room	1,020
Leaching ,, ...	720
Evaporating ,, ...	1,600
Causticizing ,, ...	840
Miscellaneous	2,400
	16,360
Add—10 per cent. . . .	1,636
	17,996

Summary.

	£
Buildings	6,380
Equipment	17,996
	24,376

A further estimate is given by this Company for a mill working by the sulphite process, with an outturn of 10 tons of unbleached pulp in 24 hours. It reads as follows :—

	£
Buildings	5,380
Add—10 per cent. . . .	538
	5,918

Equipment.

	£
Power House plant	3,800
Boiler	1,400

	£
Wood Preparing plant	240
Digester Building plant	1,600
Blow Tank room	440
Sulphur Burner	140
Acid making plant	1,820
Screen and Wet machine	1,120
Sulphur storage and lime mixing room	150
Miscellaneous	2,200
	12,910
Add—10 per cent. . .	1,291
	14,201

Summary.

	£
Buildings	5,918
Equipment	14,201
	20,119

The cost of the buildings is based on American figures and would therefore have to be adapted to Indian conditions.

Estimate by the Stebbins Engineering and Manufacturing Co.—Another estimate is made by the Stebbins Engineering and Manufacturing Co., 74-78, Smith Buildings, Watertown, New York, for a Soda Plant, which is capable of turning out 8½ tons of dry pulp per day; cost, including materials and buildings as applied to America, £18,000.

PART VI.

CHEMICALS AVAILABLE AND THEIR COST.

(1) *Lime.*

Price of lime.—Lime, which is a very important factor, is procurable in or near all the places which have been proposed as possible mill sites.

In Burma lime can be purchased in Rangoon at annas 5 per cubic foot, it being procured from Moulmein, Kyanksé and Toungoo. In Pyinmana locally prepared lime costs 8 annas per 100 lbs. In Arakan coral-lime sells at 14 annas per cwt., being obtained from Kyanksé.

On the West Coast excellent shell-lime costs 12 annas per cwt.

(2) *Caustic soda.*

Price of Caustic soda.—It will be necessary to import caustic soda from Europe.

The price paid now by Indian mills varies from Rs. 150 to Rs. 165 per ton. In 1898, the price *ex*-ship Calcutta was as high as Rs. 174 per ton, while Sindall's figure in Rangoon for 1906 was Rs. 159 per ton.

(3) *Sulphur.*

Prices of Sulphur.—The following are the prices for 1909 quoted by the Collectors of Customs, Calcutta, Madras, Karachi and Bombay :—

	Roll sulphur, per ton *ex*-ship.	Rough sulphur, per ton *ex*-ship.
	R a. p.	*R a. p.*
Calcutta . . .	93 13 0	92 8 0
Madras . . .	..	89 12 0
Karachi . . .	93 4 0	84 4 0
Bombay . . .	91 8 0	..

Sindall in his report quotes the prices of sulphur from Sicily landed in Rangoon in 1906 at Rs. 99-12 per ton.

(4) *Bleaching powder.*

Price of Bleaching powder.—The relatively high cost of Bleaching powder makes it absolutely necessary that the percentage of bleach utilised should not exceed 12 per cent. of the weight of the raw material in a dry state. The price landed in Calcutta in 1911 was Rs. 125 per ton ; in Rangoon the price would be slightly higher and in Bombay slightly less.

(5) *Soda ash, China clay and Alum.*

Price of Soda ash.—The price of Soda ash in Calcutta is about Rs. 100 and in Rangoon Rs. 110 per ton c. i. f.

Price of China clay.—The price of China clay in Calcutta is about Rs. 45 per ton c. i. f.

Price of Alum.—The price of Alum in Calcutta is about Rs. 100 per ton c. i. f.

(6) *Coal.*

Coal is procurable in large quantities from the Raneegunge Coal Fields in Bengal. The price fluctuates enormously: in 1909, it was about Rs. 3 at the pit mouth and as much as Rs. 10 per ton in Calcutta, while Sindall's figure for Rangoon is Rs. 15 per ton. In Bombay the cost of coal comes to Rs. 15 to Rs. 18 per ton.

(7) *Freight.*

Freight of bamboos.—Freight rates by sea vary from time to time, so it is not possible to give figures of any great value ; they can, however, always be obtained from large shipping agents.

Freights quoted by the Agent for Government Consignments, Calcutta, for bamboos from Rangoon to Calcutta, are as follows :—

Steamer freight Rs. 10 per ton of 50 cubic ft.

Port and shipping charges Rs. 2-4 per ton.

Freight for Chemicals.—Freight of Chemicals, from Liverpool to Calcutta, varies from Rs. 20 to Rs. 25 per ton ; and to Rangoon, Rs. 22-8 to Rs. 26 per ton.

APPENDICES.

APPEN

Experimental Bamboo Sample Plots in the

(These figures refer to the Hlaing Yoma,

Locality.	Area of sample plot, in acres.	Type of Forest.	SPECIES. Cephalostachyum pergracile (*Tinwa*). Number of clumps counted.	Cephalostachyum pergracile (*Tinwa*). Number of new stems counted.	Cephalostachyum pergracile (*Tinwa*). Number of old stems counted.	Bambusa polymorpha (*Kyathaung*). Number of clumps counted.	Bambusa polymorpha (*Kyathaung*). Number of new stems counted.	Bambusa polymorpha (*Kyathaung*). Number of old stems counted.	Number of Experimental stems cut. Cephalostachyum pergracile (*Tinwa*).	Number of Experimental stems cut. Bambusa polymorpha (*Kyathaung*).
Compartment 28, Hlaing Yoma Reserve, Rangoon Division.	1	Teak and bamboo forest.	191	685	1,995	5	30	81		
Compartment 61, Yindaik Forest, Okkan Reserve, Rangoon Division.	1	Ditto	173	224	1,125	56	162	415	100	100
Ditto Ditto .	1	Ditto	119	198	668	79	230	582		
Ditto ditto .	1	Ditto	196	452	1,397	29	83	176		
Compartment 76, Wéywa Forests, Thonzé Reserve, Tharrawaddy Division.	1	Ditto	38	76	182	71	259	595		
Compartment 70, Wèywa Forests, Thonzé Reserve, Tharrawaddy Division.	1	Ditto	81	126	385	59	226	469		
Compartment 62, Wéywa Forests, Thonzé Reserve, Tharrawaddy Division.	1	Ditto	145	260	1,000	28	61	255	100	100
Ditto ditto .	1	Ditto	96	178	536	72	242	671		
Compartment 63, Wéywa Forests, Thonzé Reserve, Tharrawaddy Division.	1	Ditto	79	118	355	82	260	647		
Ditto ditto .	1	Ditto	135	205	702	63	145	419		
Total .	10	..	1,253	2,522	8,345	544	1,698	4,310	200	200
Average	1	..	125	252	834	54	170	431	Average of one stem.	

Note I.—New stems are those which have come into existence in one monsoon but have not

DIX I.

Rangoon and Tharrawaddy Forest Divisions of Lower Burma.

Okkan and Thonzé Bamboo areas.)

AVERAGE SIZE OF ONE STEM.				TOTAL WEIGHT OF GREEN STEMS, IN LBS.						TOTAL WEIGHT OF DRY INTERNODES, IN LBS.		YIELD OF DRY INTERNODES, IN LBS. PER ACRE.		
CEPHALOSTACHYUM PERGRACILE (*Tinwa*).		BAMBUSA POLYMORPHA (*Kyathaung*).		CEPHALOSTACHYUM. PERGRACILE (*Tinwa*).			BAMBUSA POLYMORPHA (*Kyathaung*).							
Length in feet.	Mid-girth in inches.	Length in feet.	Mid-girth in inches.	Internodes.	Nodes.	Total.	Internodes.	Nodes.	Total.	Cephalostachyum pergracile (*Tinwa*).	Bambusa polymorpha (*Kyathaung*).	Cephalostachyum pergracile (*Tinwa*).	Bambusa polymorpha (*Kyathaung*.)	Total in lbs. per acre.
27·6	5·9	32·8	8·8	1,098	147	1,245	2,039	315	2,354	840	1,414	8,254	9,255	17,509
28·6	5·6	33·6	8·9	862	211	1,073	2,228	494	2,722	674	1,670			
56·2	11·5	66·4	17·7	1,960	358	2,318	4,267	809	5,076	1,514	3,084	..	..	
28·1	5·7	33·2	8·8	9·8	1·8	11·6	21·3	4·1	25·4	7·6	15·4	8,254	9,255	17,509

passed through a second rains. Old stems are those which have passed through two or more rainy seasons.

APPEN

Experimental Bamboo Sample Plots in the Toungoo and

(These figures refer to the Pyinmana and

Locality.	Area of sample plot, in acres.	Type of Forest.	SPECIES.						NUMBER OF EXPERIMENTAL STEMS CUT.	
			CEPHALOSTACHYUM PERGRACILE (*Tinwa*).			BAMBUSA POLYMORPHA (*Kyathaung*).				
			Number of clumps counted.	Number of new stems counted.	Number of old stems counted.	Number of clumps counted.	Number of new stems counted.	Number of old stems counted.	Cephalostachyum pergracile (*Tinwa*).	Bambusa polymorpha (*Kyathaung*).
* Compartment 194 (on banks of the Kabaung river), Toungoo Division.	5*	Teak and bamboo.	..	..	..	235	752	3,915	..	..
*Compartment 194 (on slopes above the Kabaung), Toungoo Division.	1·7*	Ditto	..	..	..	146	204	2,432	..	..
*Compartment 11 (on upper slopes), Bondaung Reserve, Toungoo Division.	0·9*	Ditto	..	..	..	80	170	1,267	..	..
* Ditto ditto .	1·1*	Ditto	..	..	..	93	192	1,207	50	60
* Ditto ditto .	1·6*	Ditto	..	..	..	127	266	2,231	..	..
Compartment 16, Yanaungmyin Reserve, Pyinmana Division.	1	Ditto	..	..	..	112	479	1,212	150	140
Compartment 8, Yanaungmyin Reserve, Pyinmana Division.	1	Ditto	13	14	53	97	313	1,261		
Compartment 19, Yanaungmyin Reserve, Pyinmana Division.	0·5	Ditto	50	75	279	48	192	599		
Ditto ditto .	2	Ditto	530	1,012	2,144	36	203	637		
Compartments 15 and 19, Yanaungmyin Reserve, Pyinmana Division.	2	Ditto	212	424	1,049	65	412	1,562		
TOTAL .	16·8	..	805	1,525	3,525	1,039	3,183	16,323	200	200
Average for one acre . .	1	..	145†	277†	641†	62	189	971	Average for one stem.	

NOTE I.—Figures marked thus † are averages for
NOTE II.—Figures marked * are from enumerations made by
NOTE III.—New stems are those which have come into existence in one

DIX II.

Pyinmana Forest Divisions of Burma.

Toungoo Bamboo areas.)

AVERAGE SIZE OF ONE STEM.				TOTAL WEIGHT OF GREEN STEMS IN LBS.						TOTAL WEIGHT OF DRY INTERNODES, IN LBS.		YIELD OF DRY INTERNODES, IN LBS. PER ACRE.		
CEPHALOSTACHYUM PERGRACILE (*Tinwa*).		BAMBUSA POLYMORPHA (*Kyathaung*).		CEPHALOSTACHYUM PERGRACILE (*Tinwa*).			BAMBUSA POLYMORPHA (*Kyathaung*).							
Length in feet.	Mid-girth in inches.	Length in feet.	Mid-girth in inches.	Internodes.	Nodes.	Total.	Internodes.	Nodes.	Total.	Cephalostachyum pergracile (*Tinwa*).	Bambusa polymorpha (*Kyathaung*).	Cephalostachyum pergracile (*Tinwa*).	Bambusa polymorpha (*Kyathaung*).	Total in lbs. per acre.
..	..	53*	11*											
..	..	44*	11*											
..	..	..	..											
42	6·6	52	10·1	1,025	161	1,186	2,683	514	3,197	705	1,620	9,351	29,696	39,047
34	6·1	46	8·3	2,111	416	2,527	4,922	1,190	6,112	1,704	3,502			
76	12·7	195	40·4	3,136	577	3,713	7,605	1,704	9,309	2,409	5,122	..	..	..
38	6·3	49	10·1	15·7	2·9	18·6	38·0	8·5	46·5	12·05	25·6	9,351	29,696	39,047

5·5 acres.
Mr. Borie, Divisional Forest Officer, Toungoo.
monsoon but have not passed through a second rains. Old stems are those which have passed through two or more rainy seasons.

APPENDIX III.

Experimental Bamboo Sample Plot taken in the Arakan Forest Division of Lower Burma.

(These figures refer to the Seik, Kaladan and Lemru Bamboo Catchment areas.)

Locality.	Area of sample plot, in acres.	Type of Forest.	SPECIES. Melocanna bambusoides.	Number of experimental stems cut on which the yield is based.	Average size of one stem.		Total weight green, in lbs.	Total weight dry, in lbs.	Yield per acre, in lbs.	Remarks.
			Number of culms.		Length in feet.	Mid-girth in inches.				
Lemru Catchment area, Arakan Division.	1	Pure bamboo forest cut over 10 years ago for Taungya cultivation.	10,575	*10,575	22	3·8	27,404	16,576	16,576	The growth in the area in which the sample plot was cut, was slightly under the average.

*Note I.—All the bamboos were cut down over one acre and counted and weighed green and dry.

Note II.—This sample plot was taken by Mr. Walker, Divisional Forest Officer, Arakan.

Note III.—New stems are those which have come into existence in one monsoon but have not passed through a second rains. Old stems are those which have passed through two or more rainy seasons.

APPENDIX IV.

Experimental Bamboo Sample Plots taken in the North and West Kanara Divisions of the North Kanara Collectorate, Bombay Presidency.

APPEN

Experimental Bamboo Sample Plots taken in the North and West Kanara

(These figures refer to the Gangavalli,

Serial No.	Locality.	Area of sample plots, in acres.	Class.	Type of Forest.	SPECIES. Bambusa arundinacea. No. of clumps counted.	No. of new stems counted.	No. of old stems counted.	No. of experimental stems cut.
1	Compartment 45, Block XXV. Gangavalli Forests, West Kanara Division..	2	1st class bamboo area.	Moist deciduous forest with many *Bambusa arundinacea.*	90	291	872	100
2	Compartment 44, Block XXV. Gangavalli Forests, West Kanara Division.	1		Ditto ditto	45	112	224	52
3	Compartment 7, Block XXIV. Gangavalli Forests, West Kanara Division.	1		Moist deciduous with large clumps of bamboos.	110	206	335	102
4	Block XXV, Gangavalli Forests, West Kanara Division.	1		Ditto ditto	55	118	201	100
5	Compartment 70, Block XXIV. West Kanara Division.	1		Ditto ditto	68	149	284	50
6	Compartment 62, Block XXIV. West Kanara Division.	1		Ditto ditto	78	153	223	50
	Average per acre in 1st class area .	1		..	64	147	306	Average of one stem.
7	Compartment 8, Block XXIV. Gangavalli Forest, West Kanara Division.	1	2nd class bamboo area.	Dry deciduous .	86	113	178	50
8	Compartment 9, Block XXIV. Gangavalli Forest, West Kanara Division.	2·4		Ditto . .	46	165	242	50
	Average per acre in 2nd class area .	1		..	39	82	124	Average of one stem.
9	Gund Forests, North Division, Kanara.	5		Moist teak and bamboo forest, the growth of bamboos very fine.	144	271	1,860	1C
	Average per acre	1		..	29	54	372	Average of one stem.

NOTE I.—The figures arrived at by enumerations made in the Gangavalli Valley have also been utilized in calculating
NOTE II. —New stems are those which have come into existence in one monsoon but have not passed through a second

DIX IV.

Forest Divisions of the North Kanara Collectorate, Bombay Presidency.

Kala Nadi and Gund Slopes Bamboo areas.)

Average size of one stem.		Total weight green, in lbs.	Total weight dry, in lbs.	Weight of dry internodes, in lbs.	Weight of dry nodes and saw-dust, in lbs.	Yield of dry internodes per acre, in lbs.	Remarks.
Length in feet.	Mid-girth in inches.						
54	10·3	7,094	5,152	4,300	852	24,983	1st class bamboo forest above average.
48	9·2	3,269	2,359	1,975	384	12,762	1st class a fair average.
36	7·1	2,468	1,792	1,560	232	8,274	Ditto.
46	7·4	3,816	2,986	2,610	376	8,326	Ditto.
32	7·5	2,118	1,242	1,081	161	9,361	Ditto.
24	7·1	1,710	1,111	989	122	7,437	1st class but slightly below the average.
40	8·1	45	32	27	5	10,163	
25·2	5·9	670	528	452	76	2,631	A poor bamboo area.
42·2	7·7	1,435	1,064	895	169	1,320	A poor bamboo area on higher slopes.
33·7	6·8	21	15·9	13·5	2·4	1,975	
47	12·5	1,387	1,146	680	Not known.	28,968	
47	12·5	138·7	114·6	68·0	..	28,968	

the yield in the neighbouring valley of the Kala Nadi.
rains. Old stems are those which have passed through two or more rainy seasons.

APPEN

Experimental Sample Plots taken in the East Kanara Forest

(These figures refer to the

Locality.	Area of sample plot, in acres.	Type of forest.	SPECIES.			No. of experimental stems cut.
			BAMBUSA ARUNDINACEA.			
			No. of clumps counted.	No. of new stems counted.	No. of old stems counted.	
Mungod Forests, East Kanara Forest Division.	5	Dry deciduous bamboo forest.	404	429	3,239	100
Average per acre	1	.. ..	81	86	648	Average of one stem.

NOTE I.—These are the averages for 5 separate sample plots.
NOTE II.—These sample plots were taken by Mr. Butterworth, Assistant Conservator of Forests.
NOTE III.—New stems are those which have come into existence in one monsoon but have not passed

APPEN

Experimental Bamboo Sample Plots in the South Kanara and

(These figures refer to the Uppinangadi

Locality.	Area of sample plot, in acres.	Type of forest.	SPECIES.			No. of experimental stems cut on which the yield is based.
			BAMBUSA ARUNDINACEA.			
			No. of clumps counted.	No. of new stems counted.	No. of old stems counted.	
Compartment II, Coupe 4, Uppinangadi Range, South Canara Division.	2	Moist deciduous with many *Bambusa arundinacea.*	26	82	198	100
Average per acre	1	..	13	41	99	Average of one stem.
Kumari Forest, Kanoth Range, North Malabar Division.	1	Ditto	30	160	438	100
Ditto ditto . .	1	Ditto	50	170	331	100
Average yield per acre . . .	1	..	40	165	384	Average of one stem.
Porkado Forest, Nilambur Range, South Malabar Division.	1	Ditto	45	125	287	100
Kanakatha Range, South Malabar Division.	1	Ditto	46	131	248	..
Average per acre	1	..	45	128	267	Average of one stem.

NOTE I.—The yield is not based on figures derived from these enumerations but on the enumerations
NOTE II.—New stems are those which have come into existence in one monsoon but have not passed

DIX V.

Division of the North Kanara Collectorate, Bombay Presidency.

Mungod Bamboo area.)

AVERAGE SIZE OF ONE STEM. Length in feet.	AVERAGE SIZE OF ONE STEM. Mid-girth in inches.	Total weight green, in lbs.	Total weight dry, in lbs.	Weight of dry internodes, in lbs.	Weight of dry nodes and saw-dust, in lbs.	Yield of dry internodes per acre, in lbs.	REMARKS.
38	8·8	5·759	Not known.	3,720	Not known.	5,461	
38	8·8	57·6	..	37·2	..	5,461	

through a second rains. Old stems are those which have passed through two or more rainy seasons.

DIX VI.

North and South Malabar Forest Divisions of the Madras Presidency.

Kanoth and Nilambur Bamboo areas.)

AVERAGE SIZE OF ONE STEM. Length in feet.	AVERAGE SIZE OF ONE STEM. Mid-girth in inches.	Total weight green, in lbs.	Total. weight dry, in lbs.	Weight of dry internodes, in lbs.	Weight of dry nodes, sawdust, etc., in lbs.	Yield of dry internodes per acre, in lbs.	REMARKS.
55	10	8,765	5,803	4,679	1,124	6,550	Taken on undulating ground.
55	10	87·6	58	46·8	11·2	6,550	
61	11·1	12,525	7,867	6,487	1,380	38,792	Taken in moist deciduous bamboo forest, few new clumps.
51	10·3	7,472	4,873	4,197	676	21,026	A fair number of young clumps.
56	10·7	99·9	63·7	53·4	10·3	29,909	
63	10·2	10,995	7,206	6,200	1,006	25,544	Taken in heavy bamboo forest.
..	..	..	..	..	..	..	
63	10·2	109·9	72·1	62·0	10·1	25,544	

made by the Working-Plans Officer over an area of 426 acres.
through a second rains. Old stems are those which have passed through two or more rainy seasons.

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IN

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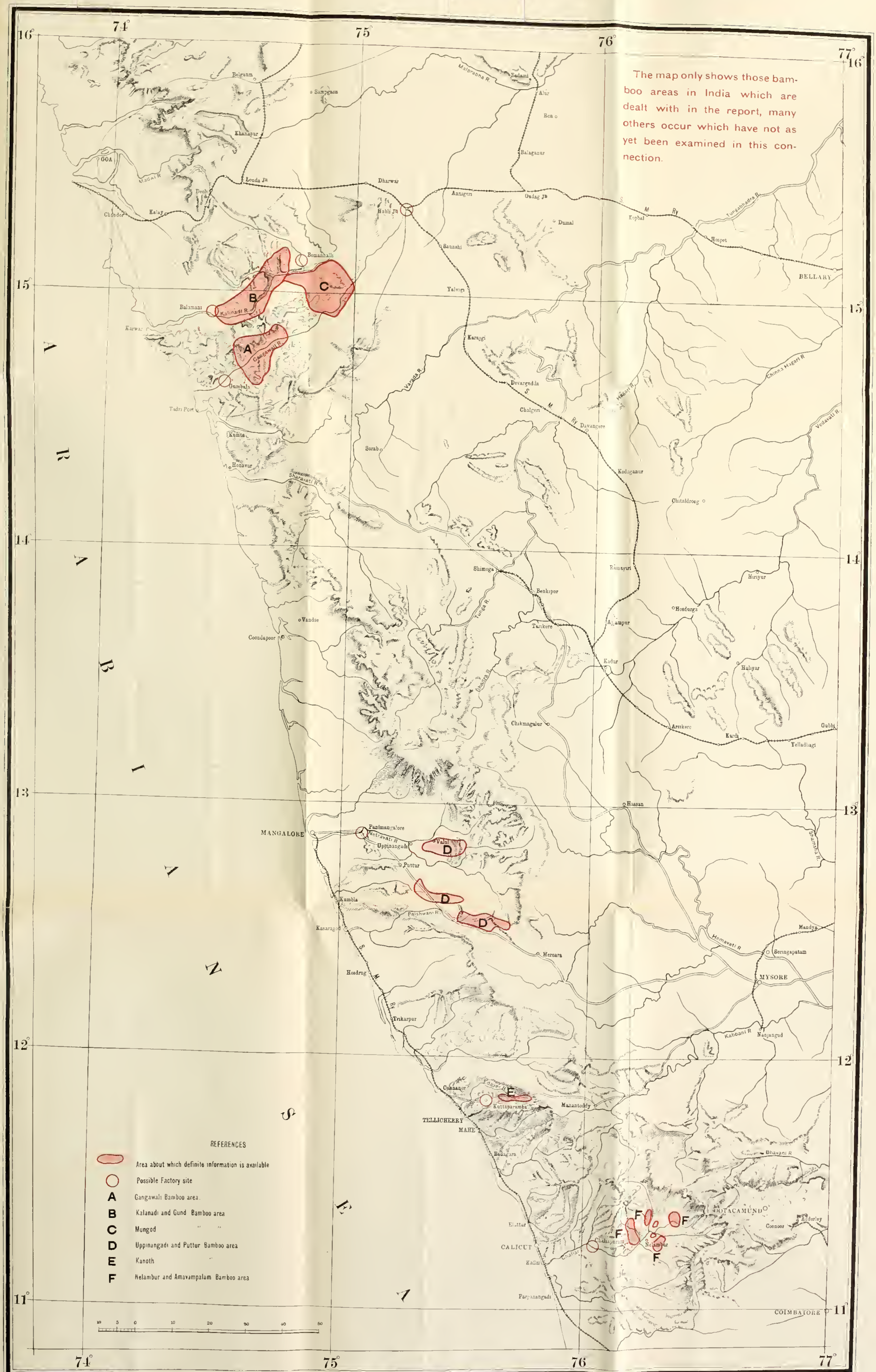

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BY
R. S. HOLE, F.C.H., F.L.S., F.E.S.
Botanist, Forest Research Institute, Dehra Dun.

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